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Seed Cane

Forty years ago A. Jaeger addressed a communication to the Hawaiian Planters' Monthly on the subject of seed cane. His letter, which was published in the issue of that journal of April, 1884, is here reproduced because of the pertinent bearing it has on the general question of better seed cane as discussed today. Mr. Jaeger wrote:

"The time, I believe, has arrived for cane planters on these Islands to pay more attention than heretofore to the selection of their seed cane.

"On most plantations it is the custom to grind all of the best cane in order to produce for the present season the largest possible quantity of sugar, and leave the poorest portion of a ratoon field for seed to plant. This is a mistake, because under such auspices sugar cane or any other plant under cultivation, will and must deteriorate according to the laws of nature, be such deterioration fast or slow, according to circumstances, it is nevertheless sure, and one ought not to be surprised at the common cry of late 'Our cane is running out.'

"The exchanging of seed cane between plantations may have proved beneficial in some instances, whilst no doubt it has done harm in others. This is, however, but trying to put off the evil day, for if much depends upon cultivation, everything depends upon the quality of seed in order to obtain the results wished for.

"The introduction of some twenty new varieties of cane from Mauritius, which have been largely distributed among our planters, will not remedy the evil. Their fate will be the same as that of our well-known kinds, unless proper care is taken of them, and in that case some varieties may prove to be a boon to our planters.

"Every plantation ought to set aside a portion of its best land and cultivate with the greatest care the cane needed for seed, which should not only be of the variety best suited to the locality, but also of the best stock obtainable. It should be looked after better than any other cane on the plantation, in order to improve the quality, rather than allow it to deteriorate.

"A planter, with whom I conversed about the matter at hand, believes that the early success which attended the cultivation of the Lahaina cane was principally due to its being carefully raised in nurseries, which was necessary at the time in order to produce sufficient seed of this variety for planting.

"It may be cheaper and in instances perhaps preferable for a plantation to spend a sum of money annually in purchasing such seed cane as it needs, if of

the kind and quality desired. In that case there would be a splendid opening for some one possessed of the suitable lands and energy to cultivate the very best quality of seed cane in order to supply those plantations in need thereof. Should this great need not as yet be apparent to many, it soon will be.

"I have always found that cuttings, roots, and even seeds taken from vigorous, healthy parent plants, will produce vigorous and healthy offsprings, which generally remain so during life, whilst those from neglected undersized stock seldom improve even under favorable circumstances, but are more liable to disease or to be attacked by insects.

"In Europe and perhaps also in America, farmers, gardeners and others have found it to their interest to procure the principal portion of seed they need annually from reliable nurserymen; those seeds having continuously proved to bring about better results than those raised by themselves.

"The cultivation of sugar cane is not much different from that of potatoes and until the last quarter of a century very little attention was paid to their cultivation as far as selection of seed was concerned; in fact, those potatoes which were not worth peeling, were picked out for seed year after year. The result of it was, that the crops of this important article of food failed. A disease, unknown during the first centuries after its introduction into Europe, made its appearance and many farmers seriously contemplated abandoning the cultivation of the potato altogether. This was about thirty years ago; but since then much has been done to improve the potato. It again yields good crops and the disease which affected them and made them unfit for human food has disappeared; but the only way this change could have been brought about was through high cultivation and careful selection of the seed. At the present day this is principally done by nurserymen, who make it a business to raise and collect seed for forestculture, agricultural and horticultural purposes, to supply the market.

"I have before me a catalogue of 1884, issued by a German seed house, which enumerates not less than 13,391 different kinds of seeds including 209 varieties of potatoes. As the prices of many seeds are quoted by the cwt., it may give an idea to what an extent these establishments are patronized."

Honolulu, March 21, 1884.

The Mexican Armyworm Parasite
(*Euplectrus Platyhypenae*)

By O. H. Swezey.

We first received this little parasite from Mexico, April 4, 1923. In cane fields at El Potrero, Vera Cruz, Mr. H. T. Osborn found caterpillars of an armyworm (*Cirphis latiuscula*) very similar to the armyworm (*Cirphis unipuncta*) we have in Hawaii. Many of the armyworms were found to be parasitized, and four consignments of them were sent to the Station at intervals of about a

week. One consignment never reached us. Another was delayed for a week in San Francisco so that it arrived with the one sent a week later. The best consignment was received on April 4.

In this consignment Mr. Osborn had put 20 caterpillars collected in the field, on which were the full grown larvae of the parasites, and 25 caterpillars having parasite egg clusters on the surface. On arrival about 200 of the parasites had already matured and were still living. More of the parasites matured in the next 3 days so that we had altogether 454 of the parasites. Three hundred and fifty-two of these were sent to the Parker Ranch at Waimea, Hawaii. The remainder were retained for experiments in rearing them at the Experiment Station.

Several kinds of caterpillars were tried with the parasites, and they were found to oviposit on any kind of armyworm or cutworm caterpillar that was available. The nut grass armyworm (*Spodoptera mauritia*) was the most convenient to make use of, as successive broods of the caterpillars could be reared in the insectary to keep up a supply on which to rear the parasites.

The first brood of parasites matured in about 2 weeks, and continual rearing was carried on for over a year. Colonies of from 100 to 1,000 of the adult parasites were sent out to the sugar plantations on the various islands and such other places as it was learned that armyworms were present. By far the larger number of them went to Hawaii where armyworms are more prevalent in certain fields of the plantations that are adjacent to grassy regions where the armyworms are apt to be present a good part of the year. Altogether 45,915 of the parasites were distributed up to May 8, 1924. The Division of Entomology of the Board of Agriculture and Forestry was also supplied with this parasite and rearing for distribution has also been carried on in their insectary.

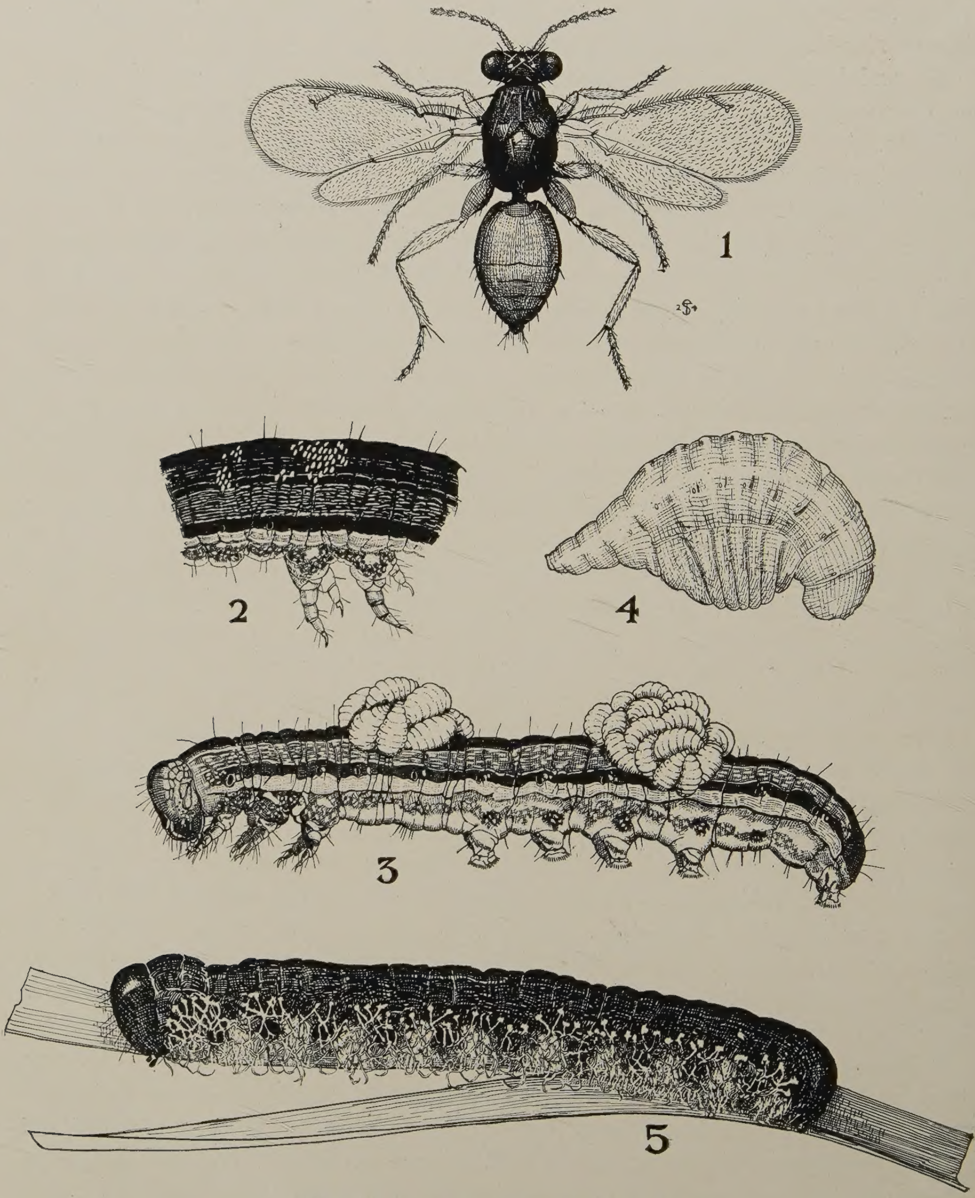
If this parasite succeeds in becoming established under our climate and conditions, it should help considerably in controlling the armyworms.

Life History.

The eggs are white when first laid, but turn black in a few hours. They are placed in clusters of from 5 to 30 on the surface of the caterpillar; are somewhat regularly arranged in rows, near to one another, but not touching. There may be several of these clusters on one caterpillar, and placed most anywhere on the upper surface or sides. As many as 50 and 75 eggs have been counted on one caterpillar. During oviposition the female parasite sits quietly on the caterpillar, which usually seems quite unconcerned about it, though at times a caterpillar is observed to try to rid itself of the parasite. Apparently the caterpillar is not paralyzed, though the parasite seems to insert its ovipositor slightly into the caterpillar before the laying of each egg.

The eggs hatch in 3 days, and the young larvae begin feeding on the caterpillar at the place where located, by inserting their mouths through the caterpillar's skin and sucking its body fluids. The caterpillar goes on feeding for about 2 days, but soon is too much affected by the feeding parasites and ultimately dies, but not before the parasite larvae finish their feeding and become full grown which is 3 to 4 days. As the parasites have remained in the same position, they become a heaped-up mass of fat maggot-like creatures. They

then separate and spin flimsy, more or less cocoon-like structures beneath the dead caterpillar thus fastening it to any object on which it may be resting. The change to the pupa stage, and eventually to adults, takes place here. The length of time for this development is 6 to 9 days, usually 7 or 8 days. The whole time from egg to maturity is thus 12 to 16 days, a very short period for the life cycle, and allows for about 20 to 25 generations per year. The adults live for about a month and must produce a large number of eggs individually; a record of one female living but two weeks was 213 eggs.



EUPLECTRUS PLATYHYPENAE
A Mexican armyworm parasite which has been introduced and widely distributed in an effort to control armyworms.

Soil Acidity: Its Relation to Root-rot*

By W. T. McGeorge.

The practice of liming in agriculture is, we might say, as old as agriculture itself. In spite of this fact the crude rule-of-thumb methods have been the rule up to a comparatively recent period. During the latter part of the last century an acid or sour condition was recognized in soils and we note the use of lime as a sour soil amendment. It was noted that most crops grew best in the complete absence of acidity or in very faintly acid soils. Poor growth under this highly acid environment was attributed to the acidity itself. For quite an extensive period this theory was accepted and we find numerous attempts to determine the lime requirement of crops and soils. While some of these merited consideration, in general, there resulted principally confusion out of which we are at last coming to understand soil acidity with greater clearness.

It has practically always been recognized that alkali soils contain alkaline salts in solution. The alkaline reaction of these soil types was considered secondary to the toxic effect of the alkaline salts themselves on plants. Acid soils are now being studied from this same angle and the presence of toxic acid salts in such soil types has been definitely proven. Among the compounds present in acid soils, which are notably absent in alkaline soils, the salts of iron, aluminum and manganese are of greatest significance. There has been a great deal of time devoted, in agricultural reasearch, to investigations dealing with the effect of the salts of these elements upon plant growth. Much of this work had been done previous to the association of their presence in acid soils with poor growth. It is beyond the scope of this report to deal with this phase of the problem. Suffice it to say that there is a great deal of contradictory evidence which indicates that the influence of these elements upon plant growth must be studied with reference to each plant type of itself.

In a study of the factors associated with the so-called Lahaina disease, which for the past twenty years or more has been of no small concern to the sugar planters, the question arose as to the presence of the salts of these elements in the soil solution of Hawaiian soils and their association with the low vitality of sugar cane. While the root-rot or Lahaina disease of sugar cane has been partially solved through the substitution of more resistant varieties it still exists and in some localities does affect the growth of the more resistant varieties. The root-rot problem has, however, been further aggravated by the appearance of the so-called pineapple wilt which appears more serious in the absence of suitable resistant varieties which can be substituted for the Smooth Cayenne. This variety, it appears, cannot be equalled in its adaptability to local environment.

In previous investigations there has been assumed a more or less close relation between pineapple wilt and Lahaina disease. There are unquestionably

* Read at the Pineapple Short Course, University of Hawaii, March 26, 1924.

a number of points of similarity. It is not within the limits of this paper to review the past work except to state that as yet no definite proof has been obtained nor any definite identification of a toxic soil constituent or organism associated with these two diseases, if diseases they are.

In planning the investigations which are now being conducted, a casual survey of the situation strongly indicated the following points. Root-rot is probably not the result of the same factor or factors in all cases. For example, we find sugar cane root-rot on a wide variety of soil types, climatic environment, altitude and locality. And I think the same may be said to apply to the pineapple plant with probably less variable conditions than those under which sugar cane root-rot, or might we better say plant failure, obtains. Also evidence and observations collected in the last twenty years strongly point toward the location of the toxic factors in the soil.

In view of the fact that the more resistant varieties have shown evidences of root-rot in our upland soils these soil types have been given first consideration. The principal characteristics of our upland soils are their acidity and phosphate deficiencies with occasional deficiencies in potash. On this basis the first phase of our work was to determine what factors associated with acid soils produce the toxicity toward plant roots. While this investigation has dealt specifically with cane roots the results are of considerable interest to the pineapple industry on account of the large acreage of upland soils cropped to this fruit.

As previously mentioned, a number of investigators in the field of soil fertility have associated salts of iron, aluminum and manganese with the low root vitality of crops grown on acid soils. Among these may be mentioned the Experiment Stations in Indiana, Massachusetts, New Jersey, Rhode Island and the Bureau of Plant Industry, U. S. Department of Agriculture. Of these Indiana is probably the pioneer. In 1913, they published a bulletin setting forth their researches upon a certain acid soil on which corn root-rot was prevalent and which responded to phosphates without any neutralization of acidity. It was very evident from this that the acidity itself was not the toxic constituent of this soil, at least when cropped to corn and further that phosphate had removed the toxic constituent which they believed to be aluminum. Iron and manganese are closely associated with aluminum in properties and have been linked with this element as being contributory factors in the toxicity of acid soils.

In order that you may understand the association of soluble salts of these elements with acid soils, it is necessary to discuss briefly the properties of the salts of these elements. When we dissolve a salt of any of these elements in water (water itself is neutral in reaction) it will undergo a change which is known in chemical terms as hydrolysis. The result is the formation of an acid through chemical exchanges between the elements making up water and the salt. That is, for example, whenever we find chloride of aluminum in solution in water the solution is acid. The question arises what soils contain soluble salts of these elements?

We have only recently completed a very careful study of the acid island soils which clears up this point. On the basis of this work it is now only necessary to determine the soil reaction in order to definitely establish the presence or absence of these acid salts. In determining the reaction we have available two

methods, namely, the hydrogen electrode or the use of indicators. A brief explanation may be essential at this point.

The old methods of determining the lime requirement of soils have, in a large measure, been supplanted by the use of what we term the pH scale. This, to the practical field man, may appear a mysterious term, yet, in fact, it is the personification of simplicity. On this scale we take pure water which is neutral in reaction and assign to it the value pH 7.0. Points on the scale above 7.0 are applied to alkaline soils. Island soils rarely go above 8.0, the coral lands being our most alkaline types. Mainland soils containing black alkali run much higher. Points on the scale below 7.0 are applied to acid soils, increasing acidity being indicated by the lowering points on the scale. Our most acid soils are usually slightly above 4.0.

Our first problem then was to determine the presence of aluminum and its associated salts in our acid soils and the reaction at which it is possible to have these acid salts present. For this work we chose a series of soils ranging in pH from 4.2 to 8.0. The actual soil solution was removed from each and in this solution the soluble salts separated from the colloidal forms. It was found that all soils below a pH of 5.8, or very close to this point, contained acid salts of iron, aluminum and manganese in solution while those above this point did not. It should be remembered in this connection that the soils between pH 5.8 and 7.0 are acid. In other words an acidity of pH 5.8 or greater is an essential factor. This applies to the salts of manganese as well as aluminum and it is interesting to note in this connection that we have yet to find a highly manganiferous soil with manganese in the soil solution. The pH on all samples of this type are above 5.8 and the manganese is present only in forms insoluble in the soil solution.

Having established beyond question the presence of these acid salts in Hawaiian soils, what of their action upon root growth? In an extensive series of water, sand and soil cultures we have proven a high degree of toxicity in aluminum salts toward cane roots. Manganese salts, while they appeared to effect a slight disturbance in the leaves, are apparently without influence upon the roots. Iron salts, our results indicate, may be entirely disregarded as being a factor unless probably in our poorly aerated types where we have ferrous forms present. Sugar cane roots in the presence of aluminum first give indications of distress by a curling or fish-hooked appearance on the root tips. Later the root hairs, the feeding roots in other words, weaken, rot and drop off the main roots.

Whether or not aluminum salts are toxic toward pineapple roots has as yet not been definitely determined. It is, however, definitely certain that pineapple wilt is widely prevalent on acid soils in which we have found aluminum and manganese salts in abundance. Among such districts may be mentioned Kapaa, Kauai, and the Kaneohe district on Oahu.

The correction of aluminum toxicity in acid soils is a very simple procedure although in some cases not entirely economical. The theory itself is simple, two methods being at our disposal. We may lime the soil to a reaction range sufficient to bring it within the range at which aluminum salts are insoluble, or we may add superphosphate which will combine with the aluminum to form the insoluble aluminum phosphate. The toxic action of aluminum on the plant is not definitely understood. I will, therefore, avoid a discussion of the several theories

except to state that it does not appear to be a direct toxic action but rather produces a phosphate deficiency in the plant. In some cases response has not been obtained either with liming or phosphate but only after satisfying a potash deficiency also. In other words, where the plant is properly nourished aluminum seems to have little or no toxic effect and we have proven this point in the nutrition of sugar cane by growing in cultures with the roots divided; that is, half of the roots growing in a strong aluminum solution and half in a well balanced nutrient.

In applying these corrective theories in soil pot cultures using 40 pounds soil per pot we have obtained wonderful stimulation of root growth and tops as well from phosphate applications. Lime, thus far, has proven less effective. The latter point was rather expected but is being given further study for therein lies the most economical solution of the problem. It is believed that the action of the lime is very much slower and that it may take several years to function and also that it will require the determination of the associated deficiency of potash or phosphoric acid. The action of the phosphate is immediate but very heavy applications are necessary and in view of the fact that it does not change the reaction of the soil it is only a matter of time until we will again have soluble aluminum present as the potential supply is unlimited.

During the course of our investigations two observations were suggestive of possible application to the pineapple planters. I have reference in the one case to the fact that we found that even though one-half of the sugar cane roots were growing in a solution of aluminum, if the other half were drawing nutrients from a well balanced nutrient solution the plant seemed to grow normally. This suggests the possibility of stimulating the pineapple plants on acid soils by supplying the deficiency of potash or phosphoric acid through the medium of the roots encircling the stalk at the base of the leaves. In the other case, in view of the fact that lime applications are productive of chlorotic leaves it is suggested that crude potassium carbonate may be substituted for lime as a neutralizer of acidity at the same time supplying potash as plant food to the plant.

In order that you may correctly interpret the preceding discussion I will state that it is not the intention to convey to you or to claim, a solution of the pineapple wilt problem but rather to present to you one phase of our soil studies on the factors associated with sugar cane root-rot which appears also to be associated with pineapple wilt. It is my belief that your wilt problem will, like our own root-rot problem, be found to be due to a number of different factors separately or together. I base this statement on my impression that the so-called wilt may be found on a number of widely varying soil types and we naturally expect to find different factors contributing under such conditions. I do, however, firmly believe that aluminum and manganese salts are the principal contributory factors on all pineapple soils with a pH lower than 5.8 and your acreage planted on such types is extensive.

Measurement of Irrigation Water

Rules for Submerged Orifice Installation.

By R. J. Lyman.

The flow of water through an orifice has been found to conform closely to the formula:

$$Q = C\,A\sqrt{2\,gh}$$

Q = Cubic feet per second, or sec. ft.
C = Coefficient (value usually between .61 and .70).
A = Area of orifice in sq. ft.
g = Acceleration of gravity (or 32.16).
h = Pressure head in feet.

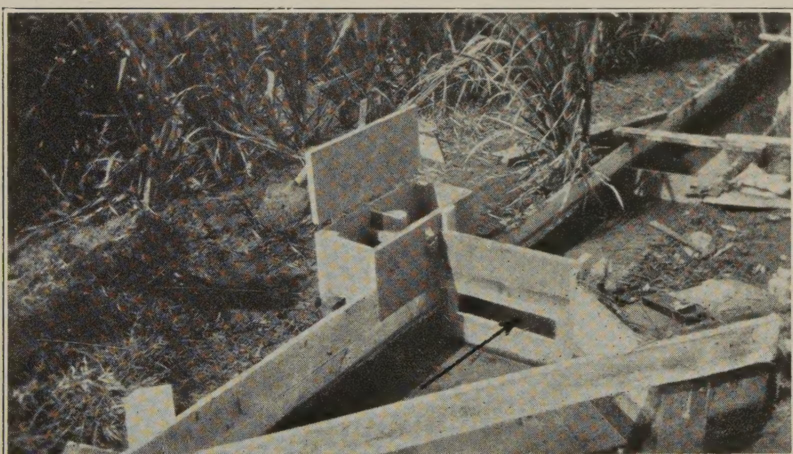


Fig. 1. Above picture shows the installation of a ¾ square foot orifice and a Great Western submerged orifice meter on the Hawi Mill, Kohala District.

The water flows through the orifice because of the pull of gravity, and the speed with which it flows is dependent principally on the pressure head. These two factors are, therefore, associated under the square root radical. Gravity is not 100 per cent effective, however, in its pull on the water. In fact it is only about 16 per cent effective. The effectiveness has been found by experiment to be in proportion to the factor $\sqrt{2\,gh}$ for different pressure heads, but the product from this factor gives an effectiveness of 25 per cent on the average. Hence, the final product must be reduced by a multiplier the value of which should be .64 in this case to equal 16 per cent.

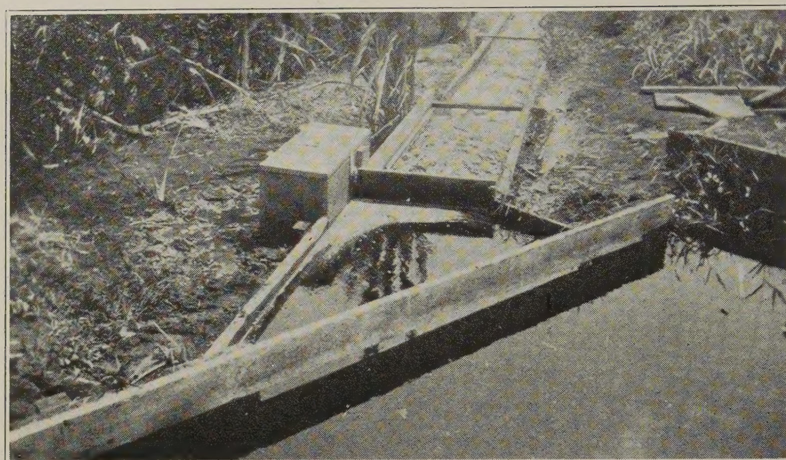


Fig. 2. Shows the same installation after the water has been turned on.

This is the explanation of the origin of the coefficient value. This coefficient value will vary according to the installation conditions. For ordinary conditions its value will range from .62 to .65. It may be stated here that conditions sur-

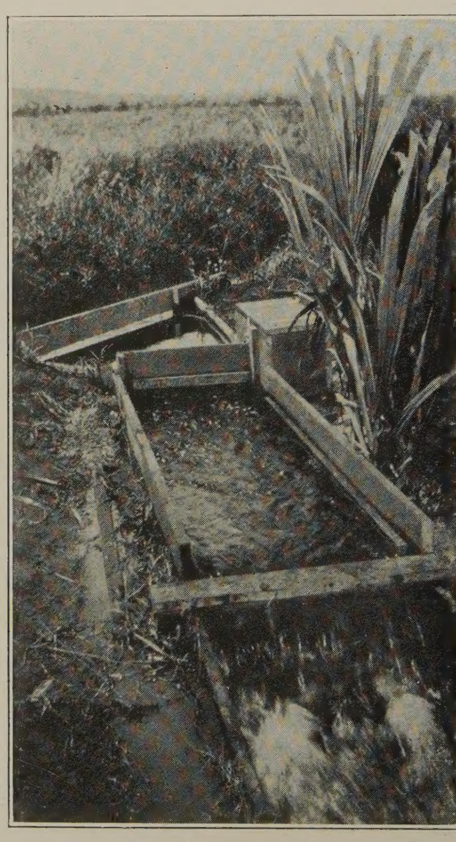


Fig. 3. The same installation as shown in cuts one and two. Note the check board about eight feet below the orifice, which insures submergence of the orifice opening.

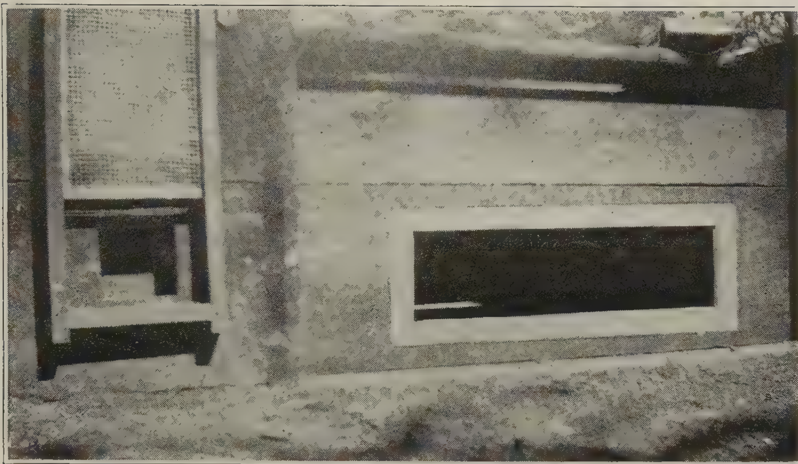


Fig. 4. An orifice and meter installation on the Ewa Plantation. The screens on the left are elevated to show the intake to the meter chamber.

rounding a weir installation may cause a larger variation from the standard weir formula than this. It may be well to also call attention at this point to the fact that the weir formula of discharge is fixed, whereas the orifice formula is flexible and may be adapted to any flow conditions.

The variability of factor C is due to conditions surrounding the installation. If an orifice is larger than 1/10 the area of the channel of approach the coefficient will tend to be higher than .62. If the bottom contraction is low (less than 6″ for a 12″ [vertical] orifice) the coefficient will be higher than .62. If the orifice is not flush with the upper face of the structure but is set in the box a few inches down from the face a velocity of approach will develop before the water reaches the orifice. The coefficient will be slightly higher for increasing sizes of orifices. However, the coefficient for an orifice 12″ by 84″ will be very

Fig. 5. Another orifice and meter installation on the Ewa Plantation. Mr. J. M. Watt is in charge of installation at the Ewa Plantation.

little higher than for a 12″ by 12″ opening, providing the same proportionate channel of approach conditions prevail.

The following general rules for orifice installation may therefore, be stated:

1. For orifice areas under 5 sq. ft. the area of the channel of approach should be 6 to 10 times the orifice area. Quietness of approach of the water to the orifice is the principal factor in the accuracy of measurement.

2. The approach basin should extend 12 to 20 feet up stream from the structure.

Fig. 6. A square foot orifice installation on the Ewa Plantation. Note the large approach basin above the orifice, which insures uniform accuracy.

3. The water must be made to flow at a right angle and with the principal velocity in the center in approaching the orifice.

4. The orifice should be flush with the upper face of the box to obtain all the side contraction possible.

5. The box should be at least 2 feet wider than the orifice length.

6. An oblong orifice is to be preferred to a square one.

7. The orifice edge should be lined with metal. The edges should project at least ⅜″ from the frame.

8. As the formula of discharge applies to a submerged orifice it is necessary to keep the orifice under water at all times. A check board may be required to accomplish this. This check board should be located far enough down stream so as not to interfere with the orifice flow.

9. With each orifice installation a pair of connected wells above and below the orifice at one side should be provided to obtain accurately the pressure head acting on the orifice.

The following is a table of discharge for 1 sq. ft. to 5 sq. ft. orifices in sec. ft. and million gals. per 24 hrs. (based on coefficient .63):

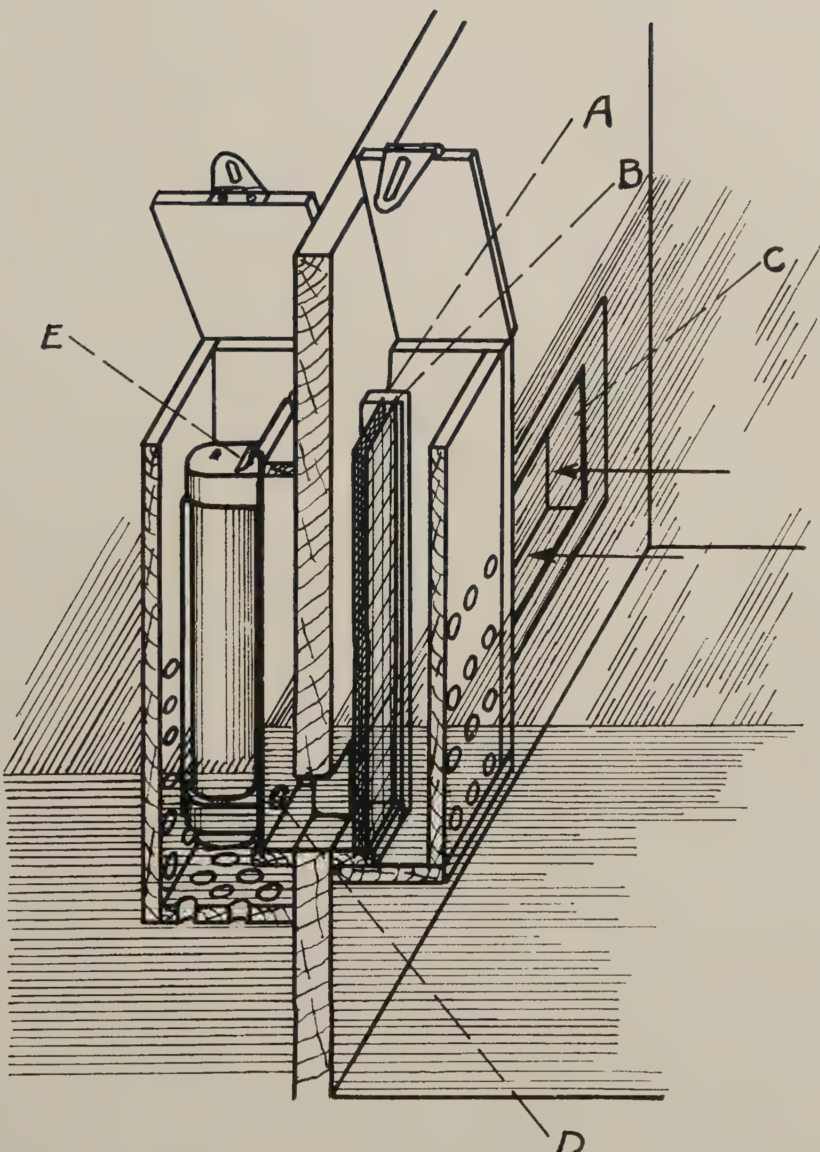


Fig. 7. Above is a sectional view of a Great Western orifice meter installation, shown as if cut through the orifice board and the boxes used to protect the meter and screens.

The main flow of water is in the direction of the arrows through the submerged orifice "C." A small proportion of the water flows through the screens "B" and "A," and enters the meter through hole "D," rotating the meter turbine at a speed dependent on the pressure head (or difference in water levels between inlet and outlet.)

The meter is geared to compute the water flowing through the main orifice in acre feet, which may be read directly at "E."

Orifice area	1 sq. ft.		2 sq. ft.		3 sq. ft.		4 sq. ft.		5 sq. ft.	
Head In feet	Sec. Ft.	Mil. Gals.	Sec. Ft.	Mil. Gals.	Sec. Ft.	Mil. Gals.	Sec. Ft.	Mil. Gals.	Sec. Ft.	Mil. Gals.
.03	.88	.56	1.75	1.13	2.63	1.70	3.50	2.26	4.38	2.83
.04	1.01	.65	2.02	1.30	3.03	1.96	4.04	2.61	5.05	3.26
.05	1.13	.73	2.26	1.46	3.39	2.19	4.52	2.92	5.65	3.65
.06	1.24	.80	2.48	1.60	3.71	2.39	4.95	3.20	6.19	4.00
.07	1.34	.87	2.67	1.72	4.01	2.58	5.35	3.46	6.68	4.32
.08	1.43	.92	2.86	1.84	4.29	2.77	5.72	3.69	7.14	4.60
.09	1.52	.98	3.03	1.95	4.55	2.94	6.06	3.91	7.58	4.89
.10	1.60	1.04	3.20	2.06	4.79	3.10	6.39	4.13	7.99	5.15
.12	1.75	1.13	3.50	2.26	5.25	3.39	7.00	4.52	8.75	5.65
.14	1.89	1.22	3.78	2.44	5.67	3.66	7.56	4.88	9.45	6.10
.16	2.02	1.30	4.04	2.61	6.06	3.91	8.08	5.22	10.10	6.52
.18	2.14	1.38	4.28	2.76	6.43	4.15	8.57	5.53	10.72	6.92
.20	2.26	1.45	4.52	2.91	6.78	4.37	9.04	5.84	11.30	7.30
.22	2.36	1.53	4.72	3.05	7.08	4.57	9.44	6.10	11.80	7.62
.24	2.47	1.60	4.94	3.20	7.41	4.78	9.88	6.39	12.35	8.00
.26	2.58	1.67	5.16	3.33	7.74	5.00	10.36	6.69	12.90	8.32
.28	2.67	1.72	5.34	3.45	8.01	5.13	10.68	6.89	13.35	8.61
.30	2.77	1.79	5.54	3.58	8.31	5.37	11.08	7.16	13.85	8.94
.32	2.86	1.85	5.72	3.69	8.58	5.54	11.44	7.38	14.30	9.22
.34	2.95	1.90	5.90	3.81	8.85	5.70	11.80	7.60	14.75	9.52
.36	3.03	1.96	6.06	3.91	9.09	5.87	12.12	7.82	15.15	9.77
.38	3.11	2.01	6.22	4.02	9.33	6.02	12.44	8.02	15.55	10.01
.40	3.20	2.07	6.40	4.13	9.60	6.20	12.80	8.26	16.00	10.32
.42	3.27	2.11	6.54	4.22	9.81	6.33	13.08	8.44	16.35	10.55
.44	3.35	2.16	6.70	4.33	10.05	6.49	13.40	8.65	16.75	10.80
.46	3.43	2.21	6.86	4.42	10.29	6.65	13.72	8.86	17.15	11.10
.48	3.50	2.26	7.00	4.52	10.50	6.78	14.00	9.04	17.50	11.30
.50	3.57	2.31	7.14	4.60	10.71	6.92	14.28	9.20	17.85	11.51
.52	3.64	2.35	7.28	4.70	10.92	7.06	14.56	9.40	18.20	11.72
.54	3.71	2.40	7.42	4.78	11.13	7.19	14.84	9.57	18.55	11.97
.56	3.78	2.45	7.56	4.88	11.34	7.32	15.12	9.76	18.90	12.20
.58	3.86	2.49	7.72	4.98	11.58	7.46	15.44	9.97	19.30	12.45
.60	3.91	2.53	7.82	5.04	11.73	7.57	15.64	10.09	19.55	12.61
.62	3.98	2.57	7.96	5.14	11.94	7.70	15.92	10.28	19.90	12.83
.64	4.04	2.61	8.08	5.22	12.12	7.82	16.16	10.40	20.20	13.03
.66	4.10	2.65	8.20	5.29	12.30	7.94	16.40	10.58	20.50	13.22
.68	4.17	2.69	8.34	5.38	12.51	8.07	16.68	10.78	20.85	13.44
.70	4.23	2.73	8.46	5.46	12.69	8.18	16.92	10.92	21.15	13.62
.72	4.29	2.77	8.58	5.53	12.87	8.30	17.16	11.08	21.45	13.84
.74	4.35	2.81	8.70	5.61	13.05	8.42	17.40	11.22	21.75	14.00
.76	4.40	2.84	8.80	5.68	13.20	8.51	17.60	11.36	22.00	14.20
.78	4.46	2.88	8.92	5.76	13.38	8.64	17.84	11.50	22.30	14.38
.80	4.52	2.92	9.04	5.83	13.56	8.75	18.08	11.65	22.60	14.58
.82	4.58	2.96	9.16	5.91	13.74	8.87	18.32	11.80	22.90	14.78
.84	4.63	2.99	9.26	5.97	13.89	8.96	18.52	11.95	23.15	14.92
.86	4.69	3.03	9.38	6.06	14.07	9.07	18.76	12.10	23.45	15.13
.88	4.74	3.06	9.48	6.13	14.22	9.18	18.96	12.22	23.70	15.30
.90	4.80	3.10	9.60	6.20	14.40	9.30	19.20	12.39	24.00	15.50
.92	4.85	3.13	9.70	6.26	14.55	9.39	19.40	12.50	24.25	15.62
.94	4.90	3.16	9.80	6.32	14.70	9.50	19.60	12.62	24.50	15.80
.96	4.95	3.20	9.90	6.38	14.85	9.58	19.80	12.75	24.75	15.95

Orifice area	1 sq. ft.		2 sq. ft.		3 sq. ft.		4 sq. ft.		5 sq. ft.	
Head	Sec.	Mil.	Sec.	Mil.	Sec.	Mil.	Sec.	Mil.	Sec.	Mil.
In feet	Ft.	Gals.	Ft.	Gals.	Ft.	Gals.	Ft.	Gals.	Ft.	Gals.
.98	5.00	3.23	10.00	6.46	15.00	9.69	20.00	12.90	25.00	16.13
1.00	5.05	3.26	10.10	6.52	15.15	9.76	20.20	13.02	25.25	16.30
1.05	5.17	3.34	10.34	6.68	15.51	10.00	20.68	13.33	25.85	16.68
1.10	5.39	3.42	10.78	6.95	16.17	10.40	21.56	13.90	26.95	17.38
1.15	5.41	3.49	10.82	7.00	16.23	10.48	21.64	13.97	27.05	17.50
1.20	5.53	3.58	11.06	7.14	16.59	10.69	22.12	14.27	27.65	17.82
1.25	5.64	3.64	11.28	7.28	16.92	10.91	22.56	14.53	28.20	18.20
1.30	5.76	3.72	11.52	7.44	17.28	11.14	23.04	14.87	28.80	18.58
1.35	5.87	3.79	11.74	7.57	17.61	11.35	23.48	15.14	29.35	18.95
1.40	5.98	3.86	11.96	7.72	17.94	11.58	23.92	15.40	29.90	19.30
1.45	6.09	3.92	12.18	7.86	18.27	11.79	24.36	15.70	30.45	19.63
1.50	6.19	3.99	12.38	8.00	18.57	11.98	24.76	16.00	30.95	19.96

Note: Millions of gallons per 24 hours is .646 of second feet.

Cultivation Practices

By J. A. Verret.

Our attention was recently called to an article in the "Country Gentleman," March 29, 1924, entitled "Why do we Plow?" It is a very interesting article and will repay reading by all engaged in the raising of crops.

For some years now we have been conducting experiments here in an endeavor to answer this question for Hawaiian conditions. We shall give herewith a review of the results obtained, rather than attempt to give a theoretical discussion as to whether we should plow or not. As the years go by, we are losing more and more of our pet theories, and the demand is more and more for actual results before forming conclusions.

The results to be reported will refer particularly to the use of plows in fields with growing crops, and not to the preparation of the seed bed before planting. The two subjects are distinct and require separate studies.

We still believe it pays to make as good a job as we know how in preparing a field before planting. In doing this, special effort should be made to destroy as many weeds and weed seeds as possible, rather than do it with hoes after the cane is growing.

This may well be the most important function of seed bed preparation; that, and the thorough stirring and aeration of the soil with its exposure to sunlight for several weeks.

Summary of Experimental Results: The first cultivation experiment conducted by the Station was at Oahu Sugar Company, in Field 6, 1913 crop. The results were as follows and show no gain:

Cultivation = 61.3 tons of cane per acre.
No cultivation = 61.4 tons of cane per acre.

The next experiment to be put in was at Waipio, in Section F, for the 1916 and 1917 crops. Since that time we have harvested cultivation experiments every year.

The results obtained from these various tests are herewith summarized:

WAIPIO EXPERIMENT F, 1916 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Cultivation (hilling)	78.8	7.52	10.47
No cultivation	77.2	7.51	10.27

WAIPIO F, 1917 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Cultivation (hilling)	44.3	9.06	4.89
No cultivation	45.5	8.75	5.20

WAIPIO EXPERIMENT M, 1917 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Hilled	37.4	7.54	4.96
Not hilled	37.5	7.54	4.97

HILO EXPERIMENT 8, 1918 CROP

5 plots—Off-barred	38.7 tons of cane per acre
5 plots—Off-barred and stools split	35.9 " " " " "
5 plots—Off-barred	29.4 " " " " "
5 plots—Stools split	28.0 " " " " "

PAAUHAU SUGAR PLANTATION EXPERIMENT 8, 1918 CROP

No. of Plots	Treatment	Cane	Tons per Acre Q. R.	Sugar
4	Off-barring, middle breaking, hilling	38.0	8.64	4.39
4	Weeding with hoes only	40.3	8.53	4.72

PAAUHAU SUGAR PLANTATION EXPERIMENT 9, 1918 CROP

No. of Plots	Treatment	Cane	Tons per Acre Q. R.	Sugar
3	Off-barred	37.2	8.38	4.44
3	Not off-barred	34.9	8.33	4.19

WAIPIO EXPERIMENT B, 1918 CROP

No. of Plots	Treatment	Cane	Tons per Acre Q. R.	Sugar
36	Hilled	89.2	10.09	8.84
36	Not hilled	88.7	10.06	8.83

HILO SUGAR COMPANY EXPERIMENT 14, 1919, 1921 AND 1923 CROPS

Treatment	Tons Cane per Acre 1919	1921	1923	Avg. Q. R.	Avg. Tons Sugar per Acre
Hilled	57.0	66.8	51.9	7.88	7.44
Not hilled	60.7	68.4	51.2	7.75	7.77

HILO SUGAR COMPANY EXPERIMENT 15, 1919 AND 1923 CROPS

Treatment	Tons Cane per Acre 1919	1923	Avg. Q. R.	Avg. Tons Sugar per Acre
Off-barred, hilled, etc	55.6	51.7	8.02	6.70
Not off-barred, hilled, etc	56.2	55.4	7.99	6.98

HILO SUGAR COMPANY EXPERIMENT 16, 1919, 1921 AND 1923 CROPS

Treatment	Tons Cane per Acre 1919	1921	1923	Avg. Q. R.	Avg. Tons Sugar per Acre
Off-barred	57.1	60.7	49.3	8.28	6.73
Not off-barred	59.4	62.0	53.0	8.04	7.23

HAKALAU CULTIVATION EXPERIMENT 1920 CROP (Conducted by the Plantation)

Treatment	Tons per Acre Cane	Q. R.	Sugar
Off-barring, middle-breaking, hilling-up, etc	40.7	7.93	5.14
Not off-barred—all others same as above	42.0	7.46	5.63
No animal work, weeding and covering fertilizer with hoes	44.1	7.37	5.98

ONOMEA SUGAR COMPANY EXPERIMENT 10, 1921 CROP—STUBBLE SHAVING

Treatment	Tons per Acre Cane	Q. R.	Sugar
Stubbles shaved	41.6	7.79	5.34
Not shaved	41.5	7.44	5.58

McBRYDE EXPERIMENT 6, 1921 CROP

Hilled = 43.6 tons cane per acre.
Not hilled = 37.8 tons cane per acre.

HAKALAU EXPERIMENT 11, 1922 CROP

Treatment	Tons per Acre Cane	Q. R.	Sugar
Plows, off-barring, hilling, etc	51.7	8.12	6.36
Cultivators (no plows)	52.7	8.00	6.59
Hoes only	50.0	7.86	6.37

HAKALAU EXPERIMENT 12, 1922 CROP

Treatment	Tons per Acre Cane	Q. R.	Sugar
Plows, off-barring, hilling, etc	38.8	8.25	4.70
Cultivators (no plows)	36.8	7.99	4.61
Hoes only	40.1	8.07	4.96

HALAWA PLANTATION EXPERIMENT 1, 1922 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Plows, off-barring, hilling, etc.	29.8	8.07	3.70
Cultivators (no plows)	29.3	8.01	3.65
Hoes only	29.0	8.09	3.59

HAMAKUA EXPERIMENT 6, 1922 CROP

Treatment	Tons Cane per Acre
Plows, off-barring, hilling, etc.	23.7
Cultivators (no plows)	24.1
Hoes only	23.6

ONOMEA EXPERIMENT 12, 1922 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Plows, off-barring, hilling, etc.	50.1	10.18	4.92
Hoes only	54.0	9.73	5.55

HAWI MILL & PLANTATION COMPANY EXPERIMENT 3, 1923 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Off-barred with 6″ plow	12.7	8.34	1.55
Off-barred with 10″ plow	13.8	8.77	1.57
Off-barred with 12″ plow	13.9	8.51	1.63
Average all off-barred	13.5	8.54	1.58
Not off-barred	13.2	8.58	1.53

ONOMEA SUGAR COMPANY EXPERIMENT 13, 1924 CROP

Treatment	Cane	Tons per Acre Q. R.	Sugar
Plows, off-barring, hilling, etc.	62.5	9.15	6.83
Cultivators (no plows)	65.1	9.05	7.19
Hoes only	68.0	8.96	7.58

For convenient reference the experiments listed above are tabulated below giving the tons of sugar per acre for each treatment:

Plantation	Experiment No.	Crop Year	Plows	Cultivators No Plows	Hoes Only	Loss or Gain From Plows
Paauhau	8	1918	4.39	....	4.72	loss
Hilo Sugar Co.	15	1919	8.04	....	7.99	equal
Hilo Sugar Co.	15	1923	5.37	....	5.88	loss
Hakalau	..	1920	5.14	5.63	5.98	loss
Hakalau	11	1922	6.36	6.59	6.37	equal
Hakalau	12	1922	4.70	4.61	4.96	loss
Halawa Plantation	1	1922	3.70	3.65	3.59	gain
Hamakua Mill	6	1922	2.96*	3.01*	2.95*	equal
Onomea	12	1922	4.92	....	5.55	loss
Onomea	13	1924	6.83	7.19	7.58	loss
Avg. of 10 experiments (plows vs. hoes)			5.24	....	5.55	loss
Avg. of 6 experiments (plows vs. cultivators, hoes)			4.95	5.11	5.24	loss

* Estimated from cane yields at 8 quality ratio.

In the above experiments where plows, cultivators and hoes are compared, we find that of the ten tests, six show a loss from plowing, three show no difference and one a gain. This single gain is small, amounting to less than one ton of cane per acre and about 0.10 ton of sugar.

EXPERIMENTS HAVING TO DO WITH OFF-BARRING ARE LISTED AS FOLLOWS:

Plantation	Experiment No.	Crop Year	Off-barred	Not Off-barred	Gain or Loss From Off-barring
Paauhau	9	1918	4.44	4.19	gain
Hilo Sugar Co.	16	1919	8.12	7.99	gain
Hilo Sugar Co.	16	1921	7.45	8.12	loss
Hilo Sugar Co.	16	1923	5.10	5.86	loss
Hawi Mill	3	1923	1.58	1.53	equal
Average			5.34	5.54	

In five experiments we find that two gave a gain from off-barring, two gave a loss and one showed no difference. The average results show a loss of 0.20 ton of sugar per acre from off-barring.

RESULTS FROM HILLING ARE SUMMARIZED:

Plantation	Experiment No.	Crop Year	Hilled	Not Hilled	Gain or Loss From Hilling	
Oahu Sugar Co.	Field 6	1913	8.17*	8.17*	equal	Irrigated
Waipio	F	1916	10.47	10.27	gain	"
Waipio	F	1917	4.89	5.20	loss	"
Waipio	M	1917	4.96	4.97	equal	"
Waipio	B	1918	8.84	8.83	equal	"
McBryde	6	1921	5.81*	5.04*	gain	"
Hilo Sugar Co.	14	1919	8.33	8.79	loss	Not irrigated
Hilo Sugar Co.	14	1921	8.46	9.09	loss	"
Hilo Sugar Co.	14	1923	5.53	5.42	gain	"
Average			7.27	7.31		

Here in nine experiments, three show gains, three show losses and three give no difference from hilling. The gains in two of the tests are too small to be of consequence, being well within experimental error; on the other hand the losses are comparatively large.

The effect of plowing on the quality of the juices is indicated in the table given below:

* Estimated from cane tonnage at 7.5 quality ratio.

Plantation	Experiment No.	Crop Year	Quality Ratio Plows	Cultivators or Hoes	
Waipio	F	1916	7.52	7.51	—
Waipio	F	1917	9.06	8.75	—
Waipio	M	1917	7.54	7.54	=
Paauhau	8	1918	8.64	8.53	—
Paauhau	9	1918	8.38	8.33	—
Waipio	B	1918	10.09	10.06	—
Hilo Sugar Co.	14	1919	6.84	6.93	+
Hilo Sugar Co.	14	1921	8.00	7.53	—
Hilo Sugar Co.	14	1923	9.39	9.44	+
Hilo Sugar Co.	15	1919	6.91	7.03	+
Hilo Sugar Co.	15	1923	9.47	9.40	—
Hilo Sugar Co.	16	1919	7.03	7.44	+
Hilo Sugar Co.	16	1921	8.15	7.64	—
Hilo Sugar Co.	16	1923	9.67	9.05	—
Hakalau	. .	1920	7.69	7.37	—
Onomea Sugar Co.	10	1921	7.79	7.44	—
Hakalau	11	1922	8.06	7.86	—
Hakalau	12	1922	8.25	8.03	—
Halawa	1	1922	8.07	8.05	—
Onomea Sugar Co.	12	1922	10.18	9.73	—
Hawi Mill	3	1923	8.58	8.53	—
Onomea Sugar Co.	13	1924	9.15	9.00	—
Average	12		8.38	8.24	—

From the above list it appears that plowing has a tendency to slightly lower the quality of the cane juices. In a total of 22 tests, the plowed plots had better juices in four instances, no differences in one case. In the seventeen remaining ones the juices were poorer where plows were used. In other words, approximately six times out of seven, plowing gives a poorer juice. As before stated, the differences are small, but we believe they are significant just the same. These results are too consistent to be the outcome of chance.

Why plowing should cause this we are at a loss to explain. It may be that the root destruction by the plows, sometimes late in the season, delays the normal development of the plant, causes new root formation late, and thereby delays maturity. This is indicated by the results at Waipio where the largest juice differences are in short ratoons where the cane has less time to mature.

Summary.

Of a total of 24 experiments where plowing was compared with surface cultivation of some sort for weed control, seven show a gain from plowing, eight show no difference and nine show a loss. An average of all the tests shows a loss of about 0.2 ton of sugar per acre when plows are used.

This shows that, for average conditions, deep cultivation with plows in growing cane cannot be expected to raise the yield of sugar in itself. The benefits obtained come through weed control.

Our cultivation work must therefore be based on the most efficient methods of weed control with the least possible disturbance to the root systems

of the growing cane. If soil conditions are such that it is necessary to use plows, this should be done as early as possible, before the young cane has developed large root systems. Even then, one must know that there is some check as, until the new shoots have roots of their own they feed to some extent through the old root system by way of the old stumps, or, in plant, through the roots on the seed piece.

Results of the same nature as those obtained here are being gotten elsewhere. Some years ago, the U. S. Department of Agriculture conducted experiments, over one hundred in number, over a period of years, in about 30 different states to determine the best methods of cultivation for corn. They found no difference in the yield of corn between fields which were cultivated and those which were not, provided weeds were kept out.

In reporting the results of a cultivation experiment the Geneva Station, New York, says:

> If the experiment has a meaning, it is that cultivation is not beneficial to the corn plant except so far as removing weeds is concerned. Strangely enough we have, during the existence of this Station, been unable to obtain decisive evidence in favor of cultivation.

Bud Selection as Affecting Quantity Production

By A. D. Shamel.

Introduction.

The importance and value of selection in seed propagated agricultural crops is no longer questioned and systematic seed selection has become an established practice as an efficient means for securing improved production.

The necessity for the selection of buds in vegetatively propagated crops has not been generally recognized until during comparatively recent years. In fact the importance of bud selection has often been questioned on account of a lack of experimental evidence proving its value and from the absence of any satisfactory explanation of the phenomenon of bud variation. The principles underlying seedling variation have been worked out and accepted in the case of many plants propagated from seed. The cause of bud variation is unknown and as yet no generally accepted explanation has been offered of the fundamental principles underlying the variability of vegetative cells. For these reasons and others, perhaps some observers have refused to recognize the fact of bud variation and have denied its importance in the propagation of horticultural and agricultural crops where the plants are propagated by budding, from cuttings, or through other vegetative means.

Within recent years a growing mass of experimental evidence and scientific observations have demonstrated beyond any question of doubt the occurrence of

striking and important bud variations in many important horticultural and agricultural plants which are commonly propagated from vegetative parts. The nature and frequency of the development of such bud variations in a number of food plants are now under investigation. While it is not possible to discuss the work as a whole at this time, a brief description of the methods of study used and some data illustrating typical results secured will be presented.

Methods of Study.

The study of the possibilities of bud selection for the improvement of production through the propagation of inherently superior parent plants involves an individual plant performance-record study as a basis for selecting parent plants for propagation and a progeny test of the selected plants in order to determine whether or not their characteristics are transmitted in propagation. In other words, the bud selection studies involve the selection of parent plants for propagation, based upon their performance records and the determination of their inherent characteristics through progeny tests. The writer believes that a natural inclination for and a sympathetic attitude toward this kind of work, together with an intimate knowledge of the plants with which they are working, gained through long continued first hand study and observation, are important qualifications for workers in this line of investigation.

The detailed methods for keeping individual plant performance records vary with the kind of plant under investigation, but in general it includes securing accurate data for a period of several consecutive and normal seasons of the quantity and quality of production. From the practical point of view, simplicity in number or kind of data used in individual plant performance-record work is of very great importance. The number, weight and grade of the individual plant's product, or other comparative units of measurement of yield, must be systematically secured in order to gain a reliable knowledge of individual plant behavior as a guide for selection. The habit of growth, season of maturity, resistance to disease or other adverse environmental factors of growth, and other plant characteristics are important considerations in the selection of individual plants for progeny tests. In the progeny test fields uniform land and favorable soil and cultural conditions are to be desired except where inherent disease or other resistance is to be studied.

Improved Yields from Selection.

In order to illustrate the possibilities for securing improved yields through systematic bud selection work three recent and typical examples of achievements along this line will be described dealing with three important food crops, viz., potatoes, apples and oranges, all of which are commonly propagated vegetatively.

The work for the improvement of potatoes by hill selection described in this paper was reported by George Stewart in Bulletin No. 176, of the Utah Agricultural Experiment Station. This work was begun in 1911 with the selection of high and low yielding hills of the Bangor, Peerless and Majestic varieties. The selected hills were propagated in rows and the resulting crops were harvested as separate hills. In 1914, the Bangor and Peerless varieties were discarded on

account of their inferiority to the Majestic. Since 1914, only high-yielding hills have been selected in the crops of the Majestic progenies except in the case of a few strains possessing unusual foliage characteristics.

A comparison of the yields of the hill-selected Majestic potato crop with the crop grown from unselected stock is shown in the following table:

TABLE I.

Yields of Selected and Unselected Majestic Potato Crops for the Period of 1915-1920, Inclusive.

Year	Pedigree Selection Mg 25-1-9-20-3-15 Weight to the Hill (grams)	Pedigree Selection Mg 25-1-9-20-3-15 Acre-Yield (bushels)	Unselected Stock Weight to the Hill (grams)	Unselected Stock Acre-Yield (bushels)	Gain Over Unselected (bushels)
1915..........	1050.91	316.7	643.02	179.3	137.4
1916..........	839.40	330.7	583.70	191.2	139.5
1917..........	810.66	382.4	698.39	269.3	113.1
1918..........	771.57	311.9	580.11	202.4	109.5
1919..........	358.20	146.9	270.20	117.3	29.6
1920..........	962.12	353.4	517.60	184.8	168.6
Average......	789.61	307.0	548.83	190.7	116.3

The progenies of the selected hills not only produced a much greater average yield than the crops from the unselected stock but the tubers in the progenies were of a larger average size than the tubers in the ordinary crop as shown in the following table:

TABLE II.

The Average Number of Tubers to the Hill and the Average Weight of Tubers for the Period of 1915-1919, Inclusive.

Year	Pedigree Selection Mg 25-1-9-20-3-15 Average No. Tubers to the Hill	Pedigree Selection Mg 25-1-9-20-3-15 Average Weight to the Tuber (grams)	Unselected Stock Average No. Tubers to the Hill	Unselected Stock Average Weight to the Tuber (grams)
1915	5.84	182.11	4.48	143.56
1916	4.58	184.20	3.84	152.80
1917	5.22	153.39	4.50	151.63
1918	4.10	187.43	4.49	127.87
1919	3.83	112.38	3.26	82.83
Average	4.89	163.90	4.14	131.74

It can be seen from an examination of these tables that during the period of 1915 to 1919 inclusive, hill selection has resulted in an increase of yield amounting on the average to 190.7 bushels of potatoes per acre. Selection has not only resulted in increased yields but has also produced larger individual tubers and a higher percentage of marketable potatoes than was found in the crop grown from comparative unselected stock.

This very interesting and significant study of the possibilities of hill selection for securing improved yields in potatoes by Professor Stewart indicates clearly and forcibly that bud variations in the potato includes those shown by the larger quantity of tubers in the individual hills, or plus variants, and that through the selection of the inherently productive hills higher yielding strains can be isolated and propagated. Not only do the higher yielding strains produce more tubers per acre but also potatoes of a larger and more desirable size and of higher commercial value than those from the unselected stock. From the practical standpoint this condition means more dollars per acre as a result of bud selection work.

The apple is one of the most widely grown fruit crops in America. The apple industry has become of very great commercial importance within comparatively recent times and a large number of farmers from Maine to California are now depending upon the growing of apples for a living. Therefore, any possibility of improving the production of apples through bud selection has a widespread and important application to the welfare of our horticultural interests. Furthermore, the apple has particular interest in this connection from the fact that most of the arguments against bud selection have been based upon the theory that no improvement in production through selection has been or can be effected with apple varieties.

The results of a well planned and consistently carried out study of bud selection in apples by the Central Experimental Farm of Ottawa, Canada, as reported by M. B. Davis, assistant horticulturist of that institution, in Scientific Agriculture, Vol. II, No. 4, pp. 120-124 inclusive, are of especial interest in considering the possibilities of selection for improved production.

The Central Experimental Farm has kept a record of the yield of individual apple trees since 1896. In 1906 scions were propagated from the heaviest yielding, the heaviest and most regular yielding and the lowest yielding trees of the Wealthy variety. The scions from the three parent trees were root-grafted on Rose of Stanstead and Dartmount Crab stock. From this propagation, progeny trees were secured as follows: 17 trees from the heaviest yielding, 12 trees from the heaviest and most regular yielding and 11 trees from the poorest yielding parent tree. The progeny trees were set out in the same orchard and under as uniform environmental conditions as possible.

The average yield of the parent trees for a period of 8 years and the average total yield of their progenies for their first 9 years of production is summarized in the following table:

TABLE III.

Average Yield of Parent Trees for a Period of 8 Years and Average Total Yield of Their Progenies for Their First 9 Years of Production Expressed in Terms of Gallons of Apples.

Rank of Parent Trees	Total Yield for 8 Years of Parent Trees	Rank of Progenies	Total Yield for 9 Yrs. of Progenies	Number of Trees in Progeny
Heaviest yielding	104¾ gallons*	Heaviest yielding	57.18 gallons	17
Most regular yielding	78¾ gallons	Most regular yielding	48.38 gallons	12
Poorest yielding	41 gallons	Poorest yielding	35.22 gallons	8

* The gallon here used is the English dry measure of capacity and equals one-eighth bushel.

The progeny of the heaviest yielding parent apple tree has produced on the average about 62 per cent more crop than the progeny of the poorest yielding parent tree, while the yield of the progeny of the heaviest and most regular parent tree has been intermediate. It will be noticed that the behavior of the progenies has been consistent with that of the parent trees.

This very important investigation indicates the possibility of securing larger and more profitable production in apple varieties by propagating from inherently productive parent trees. No difference in the quality of the fruits borne by the three parent trees or their progenies in this study is reported, so that in this case we have an instance of increase in quantity of production accomplished through selection. As the parent trees were propagated from buds in vegetative parts the inherent differences in behavior exhibited by the parent trees must have been due to bud variation. The progeny differences in production as shown in this table of yields are the results of bud selection and suggest the great and fundamental importance of this work to the apple grower in the profitable growing of apple crops.

The writer and his associates have, for a number of years, been carrying on a study of bud variations of citrus trees in California for the U. S. Department of Agriculture. Department bulletins describing some of the variations discovered and studied in the course of this investigation have been published. As a part of the work of this project as large a number of propagations have been made of some of these variations as circumstances permitted. For the most part these progeny tests are of bud variations exhibiting differences of commercial quality and quantity of fruit production. An important correlation of quality with quantity of fruit has been observed in that the larger production has usually been found to be correlated with superior commercial quality, while low production ordinarily has been correlated with undesirable size, shape, texture and other inferior characteristics of commercial quality. In order to illustrate the nature and importance of these progeny tests of citrus bud variations the results of one of the typical progeny tests will be presented. This particular experiment is concerned with a study of variations in quantity of fruit in trees of the Navel orange and their transmission through bud propagation.

In 1910, the writer discovered a tree of the Thomson strain of the Washington Navel orange variety in an orchard near his house which had one large unproductive branch, the other limbs bearing a normal quantity of fruit. This tree had been grown from a single bud on a sweet-orange seedling root-stock and was eight years old when first discovered. For several years the fruiting behavior of this tree was observed and the unproductive limb was found to be consistently unproductive while the remaining branches produced normal crops. The few fruits borne by the unproductive limb resembled those borne by the normal branches so closely that they could not be distinguished after picking. The blooming habit of the unproductive branch was apparently the same as that of the normal limbs but the foliage of the unproductive limb was more scant and the leaves were somewhat more pointed in shape than on the remainder of the tree. In other words, the difference between the behavior of the unproductive branch and the other limbs of this tree was apparently one of quantity of fruit

production. This difference in behavior was consistent year after year, but whether it was inherent or not had to be determined through a progeny test.

Three progeny trees grown from buds taken from the unproductive limb and two progeny trees grown from buds secured from one of the normal branches of the parent tree were planted in the Citrus Experiment Station orchard of the University of California at Riverside on July 2, 1917. These progeny trees were grown on sour orange root-stock and were planted ten feet apart in the orchard row, the three progeny trees of the unproductive branch being followed by the two progeny trees of the normal limb.

The performance records of the trees in this progeny test are given in the following table:

TABLE IV.

Performance Records of the Progeny Trees Propagated from an Unproductive Limb and from a Normal Branch of a Tree of the Thomson Strain of the Washington Navel Orange. The Trees were Budded in the Spring of 1915 and Planted July 2, 1917.

Season	Yield in Numbers of Fruits				
	Progeny of Unproductive Limb			Progeny of Normal Limb	
	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5
1920-1921	1	3	0	18	50
1921-1922	0	0	0	61	60
1922-1923	0	0	1	56	72
Total number Fruits	1	3	1	135	182

It will be seen that the three progeny trees of the unproductive limb have produced a total of only 5 fruits thus far as compared with a total of 317 oranges borne by the two progeny trees of the normal branch. A detailed statement regarding the behavior of progeny appears in the Journal of Agricultural Research for December 8, 1923.

The results of this and other similar progeny tests indicate clearly that in the citrus, inherent bud variations of quantity of fruit exist which are capable of perpetuation through budding. In these progeny tests not only unproductive but productive progenies as well have been propagated from limb variations, showing that plus as well as minus bud variants occur which, when propagated give rise to productive strains which yield an unusual proportion of uniformly high grade commercial fruits.

The importance and value of established and proven varieties for the growing of profitable crops can hardly be over-estimated. The results of the progeny tests referred to in this paper suggest that through systematic bud selection it is possible to conserve and improve these varieties through isolating and propagating productive strains arising from inherently superior bud variations.

Drainage Reclamation in the Western States by Small Pumping Plants

By Guy R. Stewart.

Irrigation has now been practiced in the Western States for a sufficiently long period to enable us to observe some of its after effects upon agricultural land. The tracts chosen for irrigation are nearly all alluvial plains or broad valleys where the land slopes gently towards the natural drainage channels. The rainfall in these semi-arid regions is light and variable so the natural drainage of the soil has not handled any large volume of percolating water.

The greater part of these western soils are light in texture so that it would appear that excess water would move through such soils with great ease. The low rainfall has not been sufficient, however, to remove all the salts which have been formed in every soil as the result of the gradual decomposition of the rock minerals. In some cases the lime salts have been concentrated to form a calcareous hardpan, in others the sodium salts have been partly leached out and have then collected in the lower lands as alkali patches. In still other instances, the salts are distributed through the upper or lower layers of the soil in very small amounts.

With the application of irrigation water to such land an entirely new set of conditions comes into effect. Practically all the early projects have first distributed the water through unlined main ditches and laterals. This has resulted in heavy seepage losses ranging from 10 per cent up to 50 per cent or higher. Many irrigators of arid land have habitually used excessive amounts of irrigation water. All this excess water from seepage and irrigation has thrown a heavy load on the drainage capacity of these dry regions. The soluble salts of the soil have been taken up by the drainage water and carried down to lower levels. As irrigation has continued the drainage water has soon exceeded the moderate capacity of the soil. The ground water has risen, bringing up alkali salts in places, and water-logging the land in low spots.

The general remedy in the past, for such a condition, has been to line the main ditches and laterals with a concrete surfacing and install systems of tile drainage upon the land. Such treatment has been very effective, where the salts present in the soil were largely white alkali, that is, the sulfate and chloride of sodium. Where black alkali or sodium carbonate has been the principal salt it has been found extremely difficult to reclaim land which has reached a distinctly alkaline condition. In fact, up to the present time, there is no record of the complete reclamation of an area of black alkali land.

As a consequence of this difficulty, more interest is being taken in preventive drainage measures; that is, it has been found far safer to keep land from reaching a water-logged, alkaline condition, than to try and bring it back to productivity after it has been ruined by poor drainage. It may in fact be conservatively stated, that the present opinion of drainage engineers is that every irriga-

tion project should have provision made for drainage as well as for irrigation. This does not mean that all the land in the district will become water-logged, but certain areas in every district are sure to develop a high water table and need reclamation.

The latest development along this line is by the use of small pumping plants which keep the bottom water from rising above the lower levels of the soil. The success of this plan depends upon two things. The first essential is the occurrence of a permeable stratum which normally carries the percolating drainage water of the soil. Such a stratum may be located at a depth ranging anywhere from fifty to two hundred and fifty feet. If this natural drainage stratum is filled up and additional water is still added from higher levels, the water in the soil will actually be under pressure and will be continually forced upward toward the surface. This is believed to account for the phenomena sometimes observed in a tile drainage system, where water will stand close to the surface, even though a drain may be laid some ten or twenty feet away. In this instance, the water is rising from below faster than it can run into the drain by lateral flow. If the pressure is released on the lower stratum by penetrating this water-carrying layer, the drainage water has a chance to flow down in a normal manner.

The drainage wells are therefore driven down until they intercept a layer of sand, gravel or soft rock which will readily yield water to a pump. These wells commonly range in diameter, from twelve to twenty-four inches. The second essential of successful drainage is to install a pump of sufficient capacity to reduce the pressure in the water-containing stratum. This will re-establish the normal movement of water down through the soil and considerably reduce the water table in the area affected by the pump.

This method of drainage was first recommended in a report of the consulting board for the Salt River Valley Water Users' Association, issued in 1919. The board consisted of W. R. Elliott, D. W. Murphy and W. H. Code. Since that time, a series of pumps has been installed in the Salt River Valley, with very excellent results. A system of drainage pumps has also been installed in the Turlock Irrigation District and another in the Merced Irrigation District, both of which are located in the San Joaquin Valley, California.

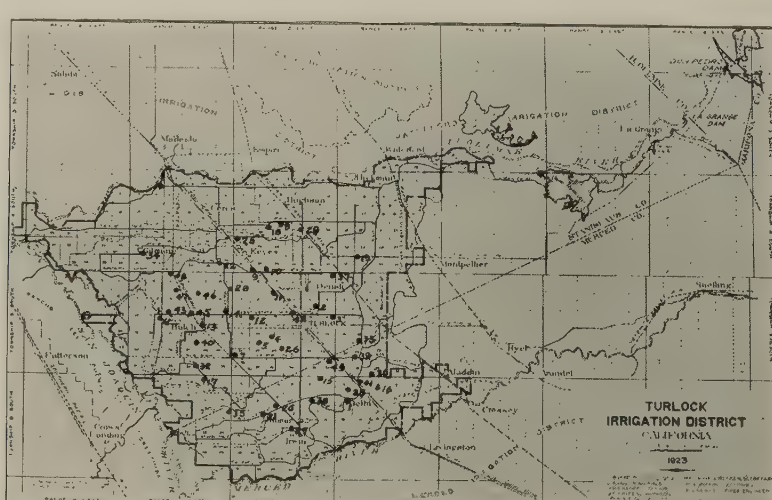


Plate I. Map of Turlock Irrigation District and location of drainage wells.

The writer recently visited the Turlock Irrigation District and examined a number of typical installations with R. V. Meikle, engineer for this district. The accompanying illustrations were furnished by courtesy of Professor Walter W. Weir, drainage engineer of the Division of Soil Technology, of the University of California.

The map of the Turlock Irrigation District, Plate I, shows the location of the first wells which were put down in this section. Additional wells are also located in and operated by the Delhi State Land Settlement. It was first believed that efficient drainage would call for a series of pumps regularly spaced throughout the entire irrigation district. A series of test wells was put down a mile apart over the 180,000 acres included in the Turlock District.

Readings were taken on these test wells throughout an irrigation season and it was found that the ground water had only risen in certain poorly-drained areas. About fifty bored wells were then put down, one to each swampy location, and fifteen horse-power, deep well turbine, electrically driven pumps were installed. The reduction of water level was extremely rapid, far more so than the results usually obtained with tile drainage systems. It only required a period of two to six weeks to materially lower the ground water in the poorly drained spots.

Plate II shows one of these poorly drained places in the Delhi Colony, before a drainage pump was installed. It will be seen that the water stood at a depth of one to two feet over a considerable area of land. Plate III shows the same poorly drained spot, six weeks later after a drainage pump was put in. The photograph was taken from exactly the same spot as Plate II. After reclamation these poorly drained areas have produced thoroughly satisfactory crops. Plate IV shows a field where a good crop of corn has just been harvested. The land shown here was another lake before a drainage pump was installed.

Plate II. Poorly drained area. Delhi Colony, before drainage.

Plate III. Same area as Plate II, six weeks later, after drainage.

In the Turlock District the pumps at present installed are fifteen horse-power, which pump 750 to 1,200 gallons per minute. It has not been necessary to run all the plants absolutely continuously, so it is planned to put in 7.5- to 10-horse-power pumps in the new installations.

One great advantage that draining by pumping possesses over tile drainage system is that pumps can be put in upon low areas where it would be impossible to find a gravity outlet for tile. Several wells in the Turlock District deliver water at a higher elevation than the pump outlet. This is accomplished by pumping directly into a concrete pipe line which carries the water up to the desired discharge point. Excessive pressures on the concrete piping are avoided by putting in standpipes which give the necessary head, but avoid undue strain

Plate IV. Field of corn just harvested. Formerly a lake until drained by pump.

on the line. Plate V illustrates such an installation in the Delhi Colony. The water is being delivered at a point some twenty feet higher than the pumps' discharge pipe.

Plate V. Standpipe to give necessary head for delivery of water at higher elevation.

The use of pumps for drainage also points to a great advance in the economical use of water. It is inevitable that some excess irrigation water will pass down into the lower portion of the soil. If this can be pumped out wherever it shows a tendency to collect in the natural drainage stratum, additional land can be irrigated and the cost of drainage reclamation can be correspondingly reduced. All the water recovered by the California drainage pumping plants is sufficiently low in salts to be excellent water for irrigation. This is likely to be the case in most localities where the pumping is done from a saturated drainage stratum. Many of the drainage pumps are located so that they discharge directly into the regular irrigation canals. Plate VI shows such a pumping plant.

Plate VI. Drainage pump discharging directly into irrigation canal.

The depth of the drainage wells in the California projects has varied from 50 to 250 feet. The depth to which they have been driven is governed by the point at which a water-bearing stratum is encountered. In some projects it is considered necessary for a well to yield a minimum flow of 2 cubic feet per second, in order to justify pumping. The draw down of the pumps is usually located at 15 to 25 feet below the surface. If the pump keeps the water down to this point it means that the pressure on the lower water-bearing stratum is sufficiently reduced so that the surface water moves downward in a normal manner.

Work in the Turlock District has also been concentrated upon curtailing seepage losses from the main canals, and laterals, by lining these ditches. Plate VII shows the typical heavy concrete lining used on the main ditches of the district.

Plate VII. Heavy concrete lining of main ditches in Turlock Irrigation District.

The possibility of applying this system of drainage reclamation to Hawaiian conditions will depend upon several factors. It will be necessary to find water-bearing stratum, located at a moderate depth, which is likely to yield a good flow of water. It should be noted in this connection that the average island soil and subsoil is much more compact than are those of the semi-arid West. The movement of water is likely to be slower but if water-bearing strata are encountered, equally good results may possibly be obtained.

There are a number of sections on the irrigated plantations which would be materially benefited by drainage. This local need for drainage is frequently shown by an abnormally high water table during the entire rainy season. In dry weather as the water table recedes, there may be some local accumulations of salt, which occasionally reach the point where the per cent of salt injures cane growth. There is then a reduction of cane yield from the checking of growth by excess water in winter and some salt accumulation during the summer season. The success achieved by drainage reclamation through pumping, in the West, would warrant a consideration of its possible application in Hawaii. The first installations will, of course, be experimental and should only be made after a careful study of the local conditions.

Growing Sugar Cane in Water Cultures

By W. T. McGeorge.

The use of water cultures in studying plant growth has found wide application as a means of noting the comparative effect of many organic and inorganic compounds upon plant roots. This method has been found to be especially adapted to investigating soil toxins or other inhibiting factors associated with retarded growth in the soils cropped to small grain crops. The ease with which these plants may be grown under such conditions is a point in favor and for this reason this method of studying soil fertility problems has been almost entirely limited to these plants. While we must recognize the limited value of water cultures, they furnish an excellent means of studying the conditions noted above. It has been demonstrated beyond question that roots in water cultures are more sensitive to toxic substances than when grown in soil. This must be considered in interpreting results.

In our studies of the factors associated with the poor root growth of sugar cane on certain of the island soils, some means of growing the plants under definitely controlled conditions in which it would be possible to observe the comparative root growth was imperative. Water cultures suggested a possible solution of this difficulty. In view of the wide variation in sugar cane (tassel) seed, as well as the short viability,* the possibility of seed appeared too doubtful. We then attempted to use the buds as follows:

* Notes on Seedling Work, Y. Kutsunai, Hawaiian Planters' Record, XXVII, p. 236.

In some of our experiments, the seed pieces were suspended in water to such a depth as to allow only the eye above the surface. In others, the seed pieces were planted in sand and soil and a limited germination of the roots and tops permitted before transferring to the water cultures. Only partial success attended these efforts. Fermentation of sugar in the seed stick promoted a heavy fungus growth which it was almost impossible to control. Germination of buds and roots

Fig. 1. Showing stage at which the shoot is removed from the seed-piece and suspended in water.

was satisfactory by this method; the difficulty lay with the maintenance of a clean culture during the period of growth. Sealing the ends of the stick with paraffin wax and sealing wax failed to correct this difficulty. It was necessary to change the culture solution almost daily in order to keep the culture medium free from fungus growth. Under such conditions, it is impossible to obtain reliable results. That is, whether to give primary or secondary importance to the influence of the fungi on the development of the plant.

In the asexual propagation of sugar cane we have two sets of roots developing. First, those issuing from the root band of the seed piece and later those issuing from the base of the stalk. The latter are more definitely associated with the nutrition of the plant. A determination of the possibility of working on the feeding roots was the next step and the question arose as to the possibility of forcing the early development of these roots. This would eliminate the seed piece entirely and its accompanying cultural difficulties. As a preliminary experiment, Lahaina and D 1135 seed pieces were planted in sand and the shoots allowed to grow to a height of 8 to 10 inches. At this height no feeding roots had appeared on the shoot. The plants were then removed from the sand culture and with a sharp knife the shoot was cut from the seed piece at its base (see

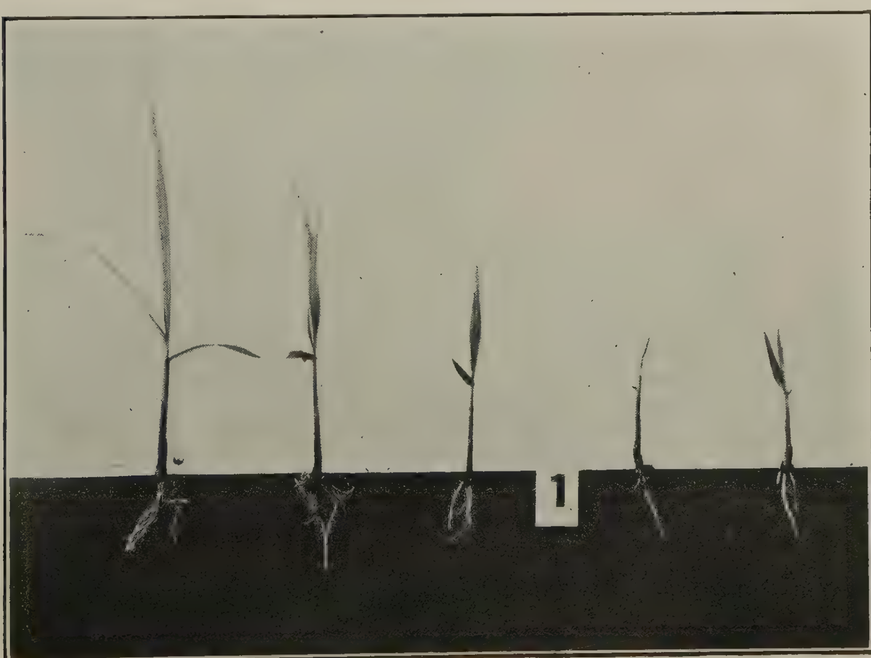


Fig. 2. D 1135 shoots grown in nutrient solution. Seed planted in soil box November 11. Shoots removed and placed in nutrient solution December 30. Height of shoots, left to right:

	Initial height	Final height
1	13.5 inches	25 inches
2	9.5 "	18 "
3	6 "	14 "
4	5.5 "	12 "
5	5.0 "	12 "

Date of photograph, Jan. 21, 1924.

Fig. 1). These shoots were then suspended in water with one-half inch of the base below the surface. This was effected by using a cork with a slot extending from one side to the center joining a hole to receive the plant. Roots appeared in four to six days time and made excellent growth thereafter. No difficulty was experienced with fungi and a clean culture solution was maintained with ease.

This method was then tried on a number of different varieties of cane using shoots of varying heights. The results obtained are best illustrated by the following six illustrations.

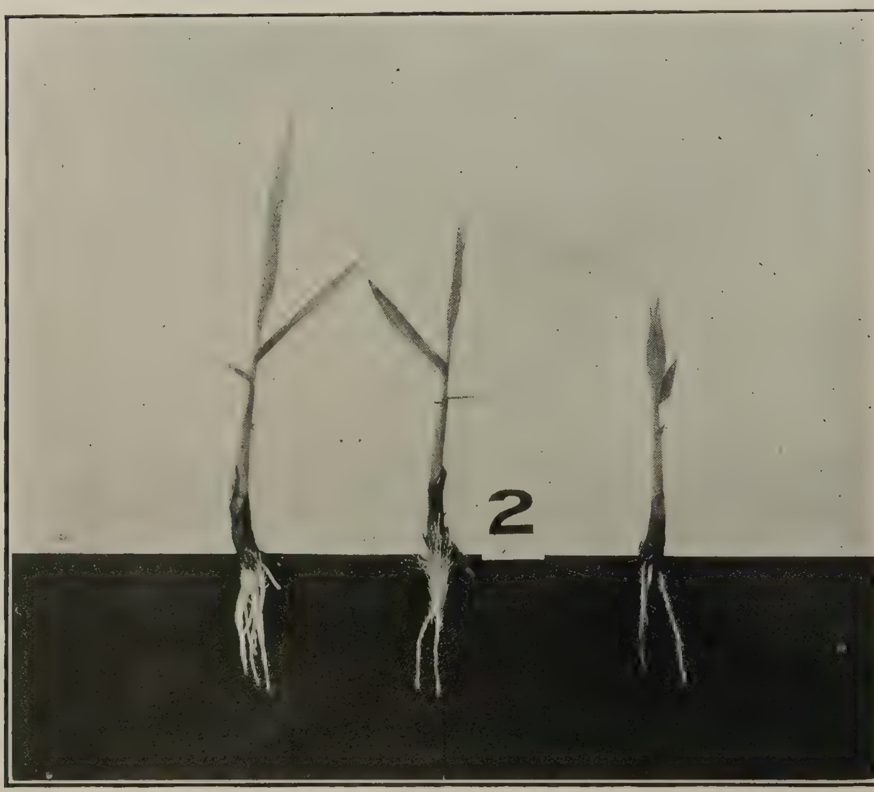


Fig. 3. H 109 shoots grown in nutrient solution. Seed planted in soil box November 29. Shoots removed and placed in nutrient solution January 4, 1924. Height of shoots, left to right:

	Initial height	Final height
1	10 inches	32 inches
2	9 "	18 "
3	6 "	15 "

Date of photograph, Jan. 21, 1924. (Note the sturdy roots.))

In the preceding experiments due consideration must be given to the slow-growing period, namely, November and December. The plants were one month old before sufficient height of plant was obtained. During the summer months one week's time is ample. The results show that shoots only 5 inches long will develop roots by this method of culture but that best results will be obtained by using shoots approximately 10 inches in height.

Fig. 4. Yellow Caledonia shoots grown in nutrient solution. Seed planted in soil box November 29. Shoots removed and placed in nutrient solution, January 4, 1924. Height of shoots, left to right:

	Initial height	Final height
1	13 inches	29 inches
2	11 "	28 "
3	9 "	29 "

Date of photograph, Jan. 21, 1924.

It may be of interest to cite several practical applications of the above procedure. The low fertility of acid soils is now attributed in part to the presence of certain acid salts, namely those of iron, aluminum and manganese. In addition to the identification of these salts in our acid soils it is also necessary to determine their effect on the growth of sugar cane. We have carried out several hundred cultures, of which Figure 8 illustrates one set, yielding very definite results on this phase of the fertility problems associated with our acid soils.

In addition to the use of culture solutions prepared in the laboratory, the actual soil solution may also be used. To illustrate the following is of interest:

Our attention was called to an insert plot of Lahaina cane in a field of H 109. The former was very badly stunted while the latter was making good growth. The soil solution was separated from this soil (for method see Hawaiian Planters' Record, XXVI, p. 234) and used as a medium for growing Lahaina and H 109 shoots. Both varieties failed to send out roots. Shoots were then rooted in

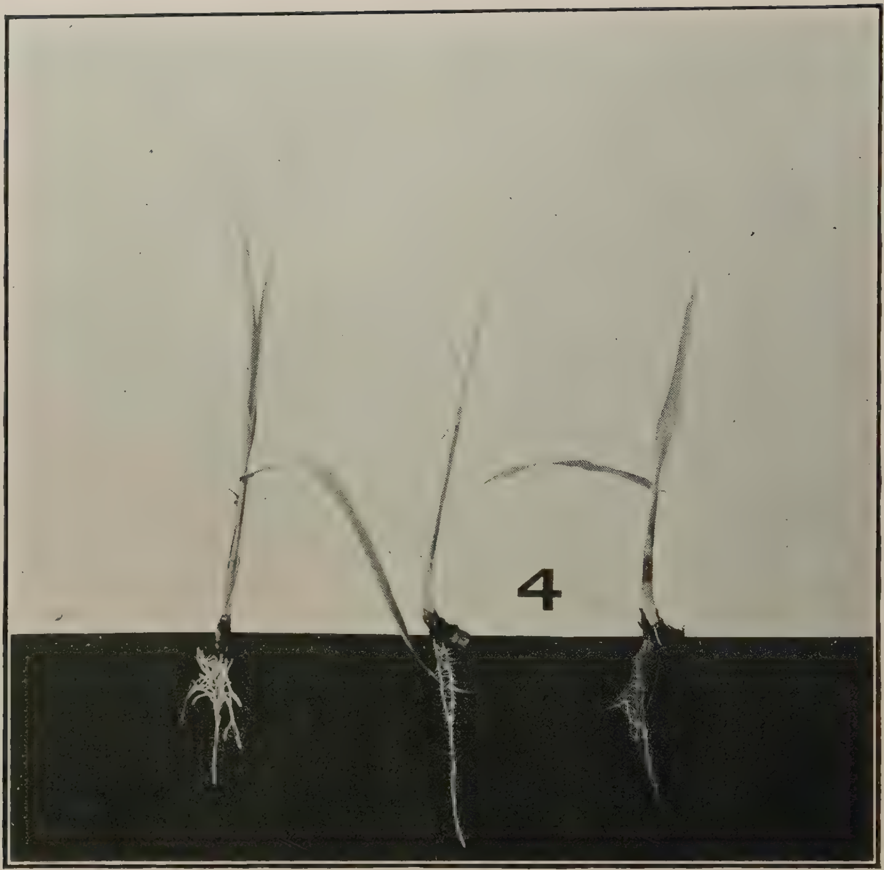


Fig. 5. Badila shoots grown in nutrient solution. Seed planted in soil box November 29. Shoots removed and placed in nutrient solution Dec. 22. Height of shoots, left to right:

	Initial height	Final height
1	14 inches	33 inches
2	8 "	18 "
3	6.5 "	18 "

Date of photograph, Jan. 21, 1924.

tap water before suspending in the soil solution. Two days after placing in the solution the Lahaina plant was plainly in distress and continued to die rapidly from this time. The H 109 showed very little evidence of toxicity beyond a faint stubby appearance on the root hairs. The analysis of the soil solution showed an extremely high concentration of salts on the basis of which a series of culture solutions was prepared and a greater resistance to salt in the H 109 variety was thereby proven.

An additional application of this method is illustrated in Figure 9. This figure is self explanatory and shows the comparative growth of D 1135 and Yellow Caledonia in the soil solution from a field on which Pahala blight is prevalent and also from a field which is free from blight.

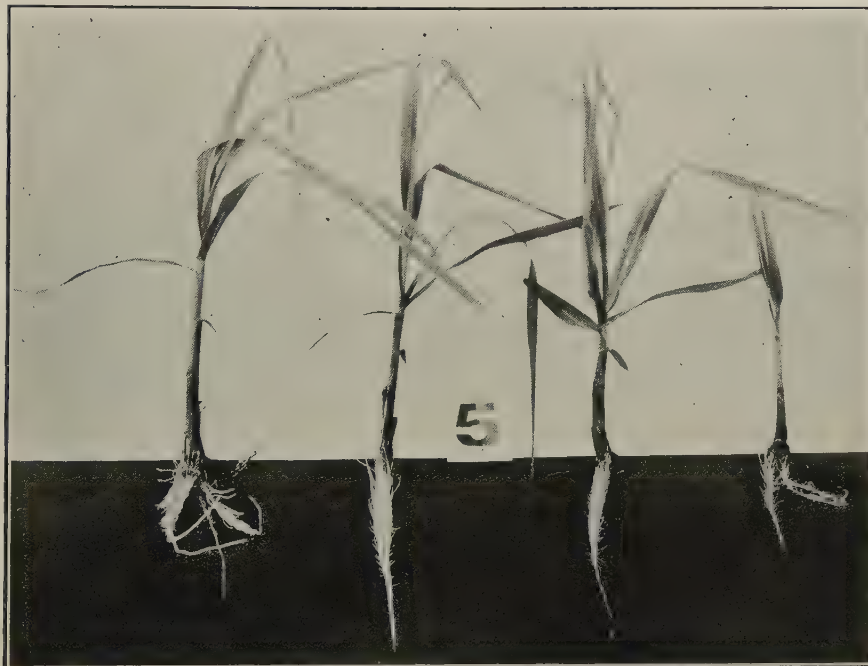


Fig. 6. Lahaina shoots grown in nutrient solution. Seed planted in soil box November 29. Shoots removed and placed in nutrient solution December 30. Height of shoots, left to right:

	Initial height	Final height
1	17 inches	45 inches
2	10.5 "	29 "
3	8.5 "	33 "
4	5.5 "	23 "

Date of photograph, Jan. 21, 1924.

It is suggested from the results obtained to date in the application of water cultures to the study of the fertility of sugar cane soils that such a procedure will lend valuable data to the solution of our problems. While heretofore this method has been applied principally to the small grain crops it may be applied with equal ease and value to sugar cane.

Fig. 7. Uba shoots grown in nutrient solution. Seed planted in soil November 29. Shoots removed and placed in water cultures December 22. Height of shoots, left to right:

	Initial height	Final height
1	11 inches	34 inches
2	16 "	30 "
3	12.5 "	27 "
4	10 "	24 "
5	6 "	22 "

Date of photograph, Jan. 21, 1924. All shoots had stooled.

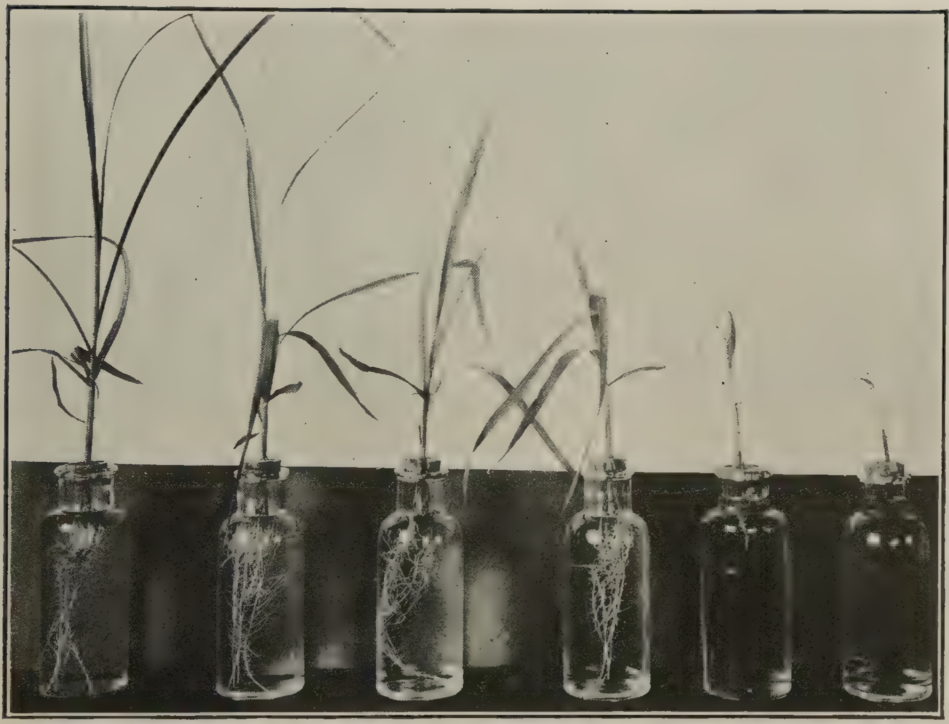


Fig. 8. Showing method of growing cane shoots in water cultures. On the left, plants growing in a nutrient solution. On the right, plants growing in the presence of toxic amounts of aluminum chloride. This figure illustrates the value of this method in studying the effect of toxic substances on cane growth. Plants one month old.

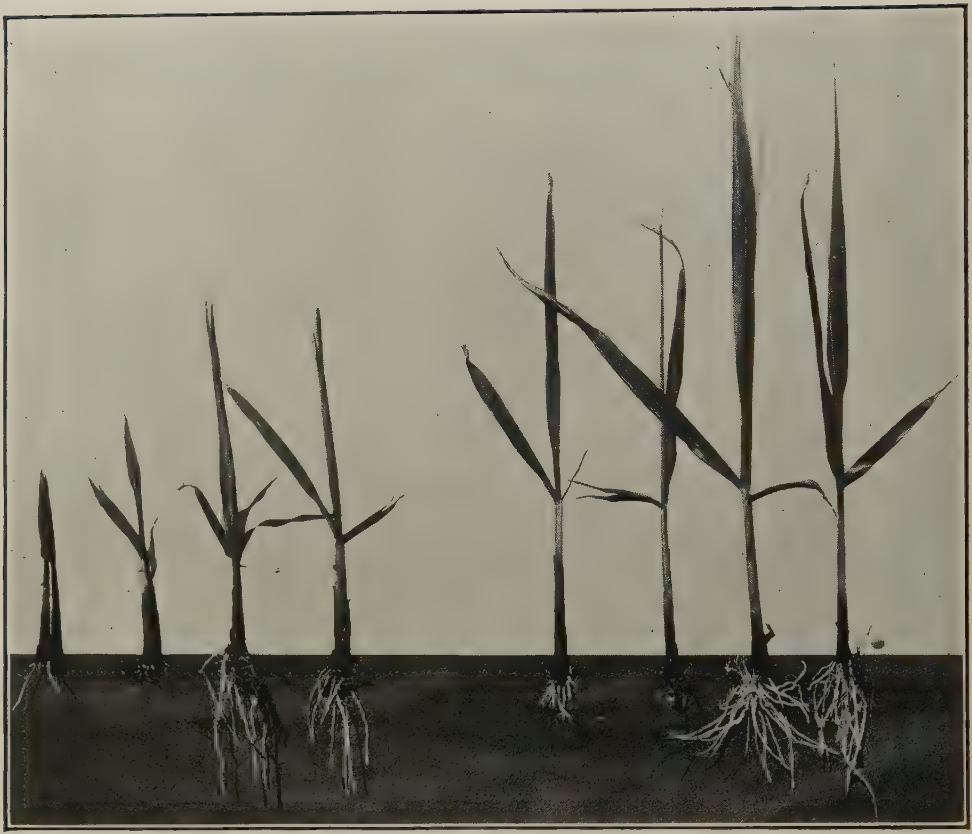


Fig. 9. Showing growth of cane shoot, two-week period, in soil solution. Reading from left to right:

1—Yellow Caledonia, soil solution from Lower Goodale. Bad blight.
2—Yellow Caledonia, subsoil solution from Lower Goodale. Bad blight.
3—Yellow Caledonia, soil solution from Wood Valley. Trace of blight.
4—Yellow Caledonia, soil solution from Mud flow. Free from blight.
5—D 1135, soil solution from Lower Goodale.
6—D 1135, subsoil solution from Lower Goodale.
7—D 1135, soil solution from Wood Valley.
8—D 1135, soil solution from Mud flow.

Salt Accumulation in Oahu Soils—Its Relation to Poor Growth of Lahaina*

By W. T. McGeorge.

In outlining a plan of study to cover an investigation of the soil types on which sugar cane root-rot is or has been prevalent, it was evident that wide variations were involved. We had previously shown the acidity of Hawaiian soils to be in part a result of the presence of soluble salts of iron, aluminum and manganese. In the Eastern and Central States it has been definitely proven that there is an association between the presence of the salts of these elements and corn root-rot. The first phase of our investigation has, on the basis of the above, involved a determination of the toxicity of these salts toward sugar cane roots and further definite information as to their presence in our soils. That is, whether or not we might expect to find them present in all soil types. While we have strong indications that plants obtain, to a certain extent, mineral matter from compounds of low solubility, we usually associate the greater toxicity with the more soluble substances.

Our work has thus far shown a definite toxic action of aluminum salts toward sugar cane roots with the least resistance in Lahaina. In searching for the soluble salts of these elements in our soils a series of soils varying in reaction from pH 4.2 to 8.0 was selected. A careful study of this series indicated that these salts were present in the soil solution only in the soils of pH 5.8 (this point not absolute but very close) or less. This in spite of the fact that all soils falling between 5.8 and 7.0 are acid. On applying the above data to island types we find

* In submitting this article for publication Mr. McGeorge wrote as follows:

"Attached herewith I submit a preliminary report on that phase of our soil investigations covering root-rot on the alkaline and faintly acid soils on Oahu. These soils, we find, contain no acid salts of aluminum.

"The evidence strongly indicates the high salt concentration to be involved. By salt I refer not to sodium chloride alone but include the salts of calcium and magnesium which are present in comparatively high concentration in the soil solution. The toxicity of sodium chloride has been suggested by Maxwell, Eckart and others. The effect of the chlorides of calcium and magnesium is a comparatively unexplored field.

"I am submitting this report in a form suitable for publishing in the Record, should you care to do so.

"On the basis of the above, I think we should plan a very complete study, in water cultures, of the effect of the chlorides and sulphates of calcium, magnesium and sodium upon sugar cane and the relative resistance of different varieties where toxicity is shown. The effect of high salt concentration upon osmotic absorption by the cane roots is another phase that should be studied. In view of observed appearance of the cane leaves, as of a lack of water, we may find some interesting comparisons of the relative osmotic absorption of Lahaina and other varieties which would be of considerable value.

"I also believe that a drainage experiment with Lahaina plantings on one or more of these high salt areas would be of considerable value in determining the association of this factor with 'Lahaina Disease'."

many of the mauka fields on Kauai as well as the Hamakua coast, Hilo and Olaa districts fall in this class. It is very evident therefore, that we must search for other factors as a cause of low root vitality in the slightly acid, neutral and alkaline types. The latter classes include practically all the lower fields of the Oahu plantations.

We were fortunate at this time in having available a small plot of Lahaina cane planted by Dr. Lyon for experimental purposes in a field of H 109. The Lahaina was plainly in great distress while the H 109 appeared to be making normal growth. We therefore obtained several hundred pounds of the soil for the purpose of removing the soil solution or soil water* for analysis and use as a culture medium for growing cane shoots.

In studying the growth of sugar cane in water cultures we have obtained best results by starting the seed sticks in sand or soil and growing therein to a height of 8″ to 15″. The shoot is then cut off the seed piece and suspended in water. In this manner shoots of Lahaina and H 109 were prepared and suspended in the soil solution from this soil. All plants except the checks which were grown in a nutrient solution died very rapidly, the Lahaina much more rapidly than the H 109. No roots had developed on the shoots of either variety. This experiment was then repeated as follows: New shoots of both the above varieties were grown in properly balanced nutrient solutions until well supplied with feeding roots and then transferred to the soil solution. Two days later, the Lahaina shoots were plainly in distress starting with a drying of the leaf tips and died rapidly from this point. The H 109 showed very little evidence of toxicity beyond a slight stubby appearance of the root hairs. These cultural experiments plainly show the greater resistance of H 109 to the conditions existant in this field and the presence of the toxic bodies in the soil solution.

The analysis of the soil solution showed the presence of 15,710 parts per million solids of which 11,090 was composed of non-volatile or inorganic compounds. It may be of interest to compare this figure with other results obtained on local soils which indicate 1,000 parts per million to be very high. The salts present in this soil were composed almost entirely of the chlorides and sulphates of calcium, magnesium and sodium. The results strongly indicate that this high salt concentration in the soil solution was the inhibiting factor. With this in mind, samples of soil were obtained from a number of areas on the island of Oahu, where Lahaina failed, where it is now making poor growth and, where it is still growing normally. The soil solution was removed from each by the displacement method and analysed. The results are given in Table I.

Description of Samples.

Soils 1 and 2. These samples are taken from an experimental plot of Lahaina cane where the cane is very badly stunted. H 109, the crop cane, other than a slight drying of the leaf tips, shows a normal growth. The field is low-lying, poorly drained and the soil a heavy clay, very sticky from salt accumulation. Sample No. 1 was taken in November before the rains had commenced, the cane

* For description of method see Hawaiian Planters' Record, XVI, p. 234.

Showing field of Lahaina and H 109 in a field of high salt concentration. Small plants in foreground are Lahaina, H 109 in background. Soil No. 1, Table 1.

Showing field of Lahaina and H 109 in a field of high salt concentration. Plants on right are Lahaina. H 109 on left. Soil No. 3, Table 1.

was only a few months old and the soil exposed to high evaporation during the entire summer. These factors would tend to promote maximum accumulation of dissolved salts by surface evaporation. Sample No. 2 was taken from this plot in February after several months of rain and during which time there occurred two heavy rainfalls.

Showing field of Lahaina and H 109 in a field of high salt concentration. Small plants in foreground, Lahaina. H 109 in background. Soil No. 1, Table 1.

TABLE I.

Soil Solution—Composition.

Results Expressed in Parts per Million Soil Solution.

	Date Sampled	Soil No.	Per Cent H_2O in Soil	Total Solids	Non Vol. Solids	Chlorine Cl	Lime CaO	Sulphur Trioxide	Magnesia MgO	Soda Na_2O	Potash K_2O
Ewa Field 14	November, 1923	1	14	15,710	11,090	6,664	3,118	1,036	1,336	2,179	202
Ewa Field 14	February, 1924	2	18	2,934	2,238	1,084	....	....	....	....	...
Ewa Field 1 D	December 19, 1923	3	22	4,558	2,548	1,239	156	82	142	918	138
Ewa Field 1 D	January 25, 1924	4	22	1,202	716	227	112	104	95	208	72
Ewa Field 1 D	December 19, 1923	5	22	3,278	1,988	1,186	760	304	720	....	121
Ewa Field 1 D	January 25, 1924	6	22	1,120	776	362	101	72	99	230	42
Waipio—Office	December 19, 1923	7	20	3,764	2,766	1,584	359	198	279	961	...
Waipio Exp. T	January 25, 1924	8	18	660	472	138	53	74	42	192	24
Waialua Gay 1	February 1, 1924	9	15	1,684	986	371	179	83	81	248	66
Waialua Gay 1	February 7, 1924	10	26	1,112	708	308	....	....	....	....	...
Oahu Field 32 A	February 24, 1924	11	18	732	532	231	....	....	....	....	...
Oahu Field 33 A	February 24, 1924	12	26	962	744	259	....	....	....	....	...
Oahu Field 34 A	February 24, 1924	13	24	1,914	1,582	819	....	....	....	....	...
Waialua Ranch 7	February 7, 1924	14	24	548	398	53	45	63	44	160	48
Waialua Ranch 4	February 7, 1924	15	20	514	312	118	45	36	31	162	57
Oahu—Kipapa	January 25, 1924	16	20	980	594	99	106	122	66	168	24
Oahu Field 12	January 25, 1924	17	21	398	240	85	39	28	25	68	52

Soils 3, 4, 5 and 6. These samples were taken from an experimental area of Lahaina cane located at a slightly higher altitude. The cane was making much better growth in this experiment. Some plots were in fact very good. It is significant that cane growing on soil No. 3 was considerably more stunted than that on soil No. 5. The reduction in salt concentration resulting from the rains is apparent in a comparison of Samples 3 and 5 with 4 and 6.

Soils 7 and 8. These samples were taken at the Waipio substation. Sample No. 7 was taken, before rains began, from a field in which Lahaina had failed. Sample No. 8 was taken from a spot where Lahaina was making pretty fair growth but had previously failed. These samples were taken from different fields and several heavy rains had occurred in the interim.

Soils 9 and 10. These samples were taken from a field at Waialua, planted to Lahaina and Caledonia. Our attention was called to this field in February so that we have no comparison to make with salt concentration previous to the rainy season. The Lahaina cane was badly stunted at this time while Yellow Caledonia appeared to be making good growth. The area is a low-lying field, poorly drained and possesses the sticky texture characteristic of high salt concentration in the soil moisture.

Showing field of Lahaina and Yellow Caledonia in a field of high salt concentration. Small plants Lahaina, and large plants Yellow Caledonia.

Soils 11, 12 and 13. These samples were taken from the peninsular fields of Oahu Sugar Company where Lahaina first failed on this island.

Soils 14 and 15. These samples were taken in mauka fields at Waialua, mauka of soils 9 and 10. Lahaina cane was making good growth in both soils. The fields are located on gently sloping land, well drained.

Soils 16 and 17. These samples were taken from fields at Oahu Plantation where Lahaina was making normal growth.

Discussion.

It is interesting to note, in this connection, the observations made in previous investigations and by plantation men which are on file or published in the Hawaiian Planters' Record.

In October, 1905, Mr. Lewton-Brain made the following notation: "Plants have very feeble hold on the soil. The root fungus mycelium is abundant about the stump and roots. But did not find the mycelium in the soil even quite close to the stump. A few weeks later with constant large irrigation the canes apparently entirely recover. In some cases plants are too far gone to recover." Cobb commenting on the above suggests the fungus must have been put in with the seed.

In a report dated October 21, 1908, Dr. Lyon suggests from observations at Ewa that the appearance of the Lahaina is not that of an infectious fungus disease but rather of poor drainage.

A report by Larsen dated February 5, 1909, after an examination of Ewa fields, gives the following significant points:

1. The cane was dwarfed accompanied by *dry leaf tips.*

2. The injury occurred mainly along the irrigation ditches. The most severely affected patches occurred near the main ditches that are constantly full of water.

3. The stellate crystal fungus was present on the roots of affected plants but was *not* abundant enough to account for the injury. It had evidently come on as a *secondary* trouble.

4. The deeper roots were usually dead while those near the surface were often healthy. The deeper dead roots were *quite free* from fungi of any sort.

He also calls attention to the lateral capillarity or seepage through the soil from the ditches and suggests the water-logged condition as a factor. Nine months later he again made observations at Ewa and noted the disease in well drained fields from which he suggests the influence of some other factor besides drainage.

In November, 1909, Dr. Lyon noted the sound condition of the seed in Ewa fields and describes the condition of the cane as of that suffering for water. He suggests that the condition of the cane is not due to fungi or nematodes, but more probably to poor drainage permitting the accumulation of undesirable salts in the soil. One year later he again observed the diseased fields with the same notations.

In October, 1911, Dr. Lyon reports growing healthy stools from seed of diseased cane and on transferring diseased stools to good soil, they developed into vigorous plants.

In a report of April 27, 1912, Mr. Eckart mentions the excellent results obtained by Mr. E. K. Bull, Oahu, by hilling up and planting in the row rather than furrow.

In 1910, Mr. Peck carried on extensive chemical and biological studies on Oahu diseased soils with little or no indication of inhibiting factors other than the deflocculated physical state. He suggested the presence of bicarbonates.

In the Annual Report for 1913, Mr. Peck mentions having found high alkalinity in some of the diseased soils.

In 1915, Mr. Agee* gave a general summary of the soil work to date on experiments with diseased fields. The following soil treatments were tried: Gypsum with and without ammonium sulphate, lime as oxide and carbonate, reverted phosphate, stable manure, extra fertilization and irrigation, cyanide, carbon black, pyrogallic acid and carbon bisulphide. No favorable results were obtained from any of the above. On the other hand, mixing 80 per cent virgin and 20 per cent affected soil gave good results in tub experiments.

Green manuring gave some response on plant cane (legumes were not irrigated).

Larsen† reports two experiments, in one of which legumes were grown one year and another only four months. In the latter experiment the cane was badly diseased.

In 1915, Speare made an extended survey of the fields of Oahu and Honolulu Plantations. The following observations are significant:

Oahu Plantation. Both mauka and makai fields affected. Almost invariably the disease is more intense and first appears in connection with watercourses, level ditches and straight ditches. If in connection with a level ditch, the cane appears in bad condition below it and good above. It will thus run along the makai side of the ditch for some distance and then after a time appear on the mauka side after which it spreads more rapidly. Similarly it seems to appear along both sides of the watercourses first. He says the cause is augmented by pump water.

Honolulu Plantation. The disease was worse in the high coral fields around Puuloa. "One striking exception is apparent in Field 17 where an area one watercourse wide is in good cane though surrounded by diseased cane. This small area receives 'night water' from the mill in distinction from the neighboring areas."

Burgess studied the problem, dealing very thoroughly with the association of black alkali which had previously been suggested by both Peck and Eckart. He found on many diseased areas a greater alkali concentration. Some significant observations are of interest. "The worst plants are always to be found along water ditches or in little sinks or basins." "It is commonly recognized that the condition of the Lahaina cane is much better this year (1917) in many fields on Oahu that have suffered from a diseased condition for the past several seasons." "It is important to note that the rainfall for the past two winters has been exceedingly heavy." On analysis he found less black and white alkali in the soils in 1917 than was present in 1915.

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* Hawaiian Planters' Record, XII, p. 374.

† Hawaiian Planters' Record, XV, p. 70.

In March, 1919, the late Mr. G. F. Renton stated, "In any dry year following a dry winter Lahaina disease spreads more rapidly than in an ordinary wet year following a wet winter."

There is abundant evidence in the preceding observations that salt accumulation in our lower irrigated fields may have been involved in the lowering vitality of Lahaina on our neutral and alkaline soils. This evidence is available both in the physiological observations upon the conditions of the plants such as dry leaf tips and indications of lack of water and in the notations of soil conditions. In the latter, may be included contiguous irrigation ditches and less appearance of the disease during years of heavy rainfall.

Both Maxwell and Eckart called attention to the toxic action of sodium chloride toward sugar cane.

We have shown by cultural experiments using the soil solution from soil No. 1 that this high salt concentration is toxic toward Lahaina while less so for H 109. Also we have shown in a preliminary experiment by making up culture solutions of known sodium chloride content that H 109 is much more resistant to high concentrations of this salt than Lahaina. There are present, however, chlorides of calcium and magnesium as well as the sulphates which are notably higher in the poor areas. Our study of the toxicity of aluminum and manganese salts in acid soils has shown in water cultures a notably greater toxic action from the chlorides. The question arises as to the effects of chlorides of calcium and magnesium.

Comparatively little has been done on the pathological effect of an excess of salts (not NaCl alone) upon sugar cane. Also of the effect of an excess or a deficiency of essential and non-essential salts upon their absorption or assimilation by the cane plant. Also we know little or nothing of the degree of selection which the different cane varieties exercise in their absorption of essential and non-essential elements. Evidence strongly indicates such a variation to be inherent in sugar cane.

The effect of high salt concentration itself, that is, its physical not physiological influence, is also little understood. The semi-permeable membrane which separates the root cell sap from the soil solution plays a very important role in absorption. It is evident therefore, that where we have a higher concentration in the soil solution than in the cell sap of the roots equilibrium tendencies will work against the absorption of water by the plant. In other words the plant will suffer for water. Antagonistic action of the elements present in the soil solution adds further to the complexities. The problem therefore, involves practically an unexplored field. Hence, while there is very strong proof in the data in Table 1, as well as the numerous observations, that salt accumulation has been involved in the low vitality of Lahaina, no simple explanation will suffice. There is a wide degree of variation in the salt concentration of the soil solution influenced principally by seasonal factors. The comparative figures in Table 1 show the marked effect of a few months of the rainy season on salt concentration. This concentration is greatest during the summer months at which time its effect upon the plant vitality is also at a maximum. The crop therefore, enters the slow-growing winter months with a reduced vitality. We must, in addition, recognize

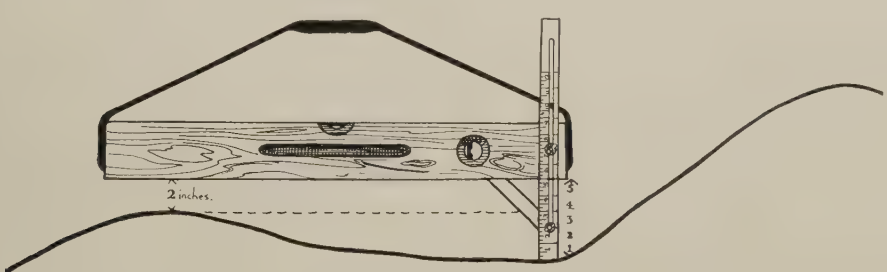
the possible injury to the root cells which will follow rapid changes in the salt concentration as this would be accompanied by wide osmotic pressure variations.

We are planning, on the basis of the above, a detailed study of the effect of the concentration and variable proportions of the sulphates and chlorides of calcium, magnesium and sodium on sugar cane which we anticipate will clear up many doubtful points regarding the role of salt accumulation in the degree of plant vitality.

The Steffee Line Gauge

Any development offers interest if it tends to add precision to sugar cane agriculture.

On steep hillsides or palis the eye is very deceptive in remaking the lines to hold irrigation water. A simple and useful device has been designed by J. B. Steffee, of the Ewa Plantation Company, to be used in this connection. He gives the following description of it:



A new line gauge has been found to be of considerable value in pulling up lines on sloping fields. It consists of an ordinary 30-inch carpenter's level with attachments of a sliding brass ferrule, graduated, and a handle for convenience. The ferrule indicates the desired depth of water in the line and the level shows how much soil should be added to the bank in order to hold the water.

It has always been the practise to have laborers work over the field, after a crop is harvested, pulling up lines without any standard to go by. A recent test with the gauge showed that these banks vary a great deal in water-holding capacity. Some lines held as little as 2¼ inches while others could easily contain 8 inches. A 2¼-inch irrigation will obviously fall far short of producing good growth results, especially during hot months and on porous soil. On the other hand, a bank holding an 8-inch irrigation is larger than is necessary and a part of the labor in making it has been wasted.

On level fields sufficiently good lines can be built up to produce good results judging with the eye without mechanical assistance, but curving lines on sloping land are frequently deceptive.

The use of the gauge will tend to standardize lines on pali fields and it is believed will work to advantage in three ways, viz:

1. Increase tonnage by insuring a sufficient uniform irrigation.
2. Eliminate unnecessary labor in pulling up too much soil for bank.
3. Tend to have a good moral effect on workers who will know that the device is going to be applied to their work and will show deficiencies.

[H. P. A.]

Soil Analysis—Its Limitations and Possibilities*

By W. T. McGeorge.

In studying the fertilizer requirements of crops and soils, soil analysis has steadily lost in favor. There are, among students of soil fertility, few remaining who place any value whatever upon the ordinary methods. During the early part of the last century, von Liebig, a German agricultural chemist, discovered that plants required a certain amount of mineral salts, the supplying of which necessarily lay through the medium of the soil solution. It was only a natural consequence of this discovery that attempts should be made to ascertain the fertilizer needs of the crop by a chemical analysis. The digestion of soils by strong acids constituted the initial attempts but it was later noted that there existed a wide variation in solubility or availability of the mineral nutrients. Thence followed attempts to measure the available mineral soil constituents and to distinguish between these forms and those not readily available for assimilation by the plant. A tangle of empirical methods was finally reached with a bewildering array of solvents and methods of extraction constituting the only results of many years' effort. Foremost among those of the old school who attached considerable value to the use of strong acid digestion was Hilgard, who considered this method a measure of the "Zeolitic" reserve. If the analysis fell below a certain percentage of any important plant food constituent it was considered deficient and application as fertilizer was recommended. In another school may be included the English chemist, Dyer, and others whose attempts to distinguish between the available and non-available mineral constituents were based on the theory that all plant roots secreted acids which aided in the solution of soil minerals. This latter theory exploded with the discovery that there was no indication that growing roots secreted any acid other than carbonic.

We might safely conclude that few attempts to associate soil analysis with soil fertility have succeeded definitely. The most notable recognition of this we find in the last "Methods of Analysis" of the Association of Official Agricultural Chemists in which the old official method has been withdrawn.

The fallacious teachings of the old school have penetrated deeply our agrarian population. A soil analysis appears as a simple and logical procedure to the practical tiller of the soil and few there are who would not readily associate with it a valuable significance in soil management. Few stop to realize that the amounts of plant food added as fertilizer are far beyond the range of accuracy of most methods of soil analysis; that the amounts required to stimulate plant growth are many times less than that already present in the soil. Modern experimental tendencies, therefore, are now being directed toward a more complete knowledge of the inherent physiological properties of plants as influenced by season, plant food balance and other factors.

* Originally published in The Louisiana Planter.

There are few soils but what contain enough mineral plant food to supply the immediate crop needs if it were available, although in establishing a permanent program it is of no small value to know the reserve and make some attempts to retain this. What is most important to recognize is our knowledge that all plants draw most heavily upon the plant food supply at certain definite seasons. Therefore, the most essential knowledge required is the degree of availability and when such is deficient to make fertilizer applications for the vital growing period.

In view of the generally recognized failure of soil analysis in diversified agriculture the question arises as to its value in a more intensive single cropping system such as is found in the sugar industry. In Hawaii, where the soils are under a continual drain, where rotation is rarely practiced, and the fields are cropped continuously it is essential to either ascertain the reserve supply or maintain this through a knowledge of the plant food removed. Marked deficiencies or abundance are usually indicated by a determination of the total soil constituents and this method therefore has some value in formulating a permanent program. That is, where fertilization shows that availability is low, attempts should be made to increase this availability by cultural methods. For this reason it is often of value to determine this reserve supply, although the data thus obtained are of no immediate value.

In attempting to determine by chemical methods the availability of soil minerals we are confronted with a more and extremely complex problem. The possible combinations in the soil are legion and in order to detect the change in soil composition which results from fertilization, which amounts are sufficient to stimulate plant growth, it is necessary to resort to methods accurate to the third or possible fourth decimal place of percentages.

Heavy fertilization on the sugar lands of Hawaii is a necessity in maintaining the high yields necessary to offset the lower cost of production in most other cane growing countries. It is therefore imperative to utilize every possible means of aiding the formulation of fertilizer practices. The question therefore arises, what is the limit to the value that can be placed upon methods of determining plant food availability?

We are limited in this to the use of water and dilute mineral or organic acids. In Hawaiian soils the high colloidal content of which imparts strong fixing powers, little success has attended the use of water extracts or analyses of the soil solution. This applies especially to phosphates. We find sugar cane makes heavy demands upon the mineral nutrients at certain definite stages of growth. It is therefore evident that a water extract or the separation of the soil solution which is too greatly influenced by the fixing power of the soil will be of little value. With our crop, adequate supplies of available plant food or the rate at which the replenishment of the soil solution is possible is the important factor rather than a determination of the actual concentration of the soil solution. Dilute acids, therefore, appear to be our only recourse. A low reserve is rarely noted in Hawaiian soils, it is mainly a question of availability.

It must be admitted at the outset that any sound theoretical principle on which to base the relation of the solvent power of any acid to the availability of any plant food constituent is entirely lacking. It is true that the solvent properties

of dilute acids under definite conditions for any phosphate or potash compound can be accurately determined. But when applied to soils other factors will greatly influence solubility, thus limiting the general application of such knowledge. It is mainly due to the above that so little value can be attached to an ordinary soil analysis where other knowledge of the soil type is lacking. The only possible value then of applying soil analyses lies in the empirical establishment of a working agreement between the solubility of mineral nutrients and response of a soil type to fertilization. In other words, it is essential to "back up" the chemical analysis with numerous field experiments and a knowledge of the feeding power of the crop along with an intimate acquaintance with other peculiarities of both the crop and soil type. Such a correlation has been established with considerable success on the sugar lands of Hawaii.

This has been made possible by an extensive series of field experiments scattered over the island plantations and supervised by the Experiment Station agriculturalists. We thus had at our disposal soil samples of known fertility.

In Hawaii, approximately 225,000 acres are devoted to sugar cane culture. We are dealing with one crop and have, therefore, no concern for the wide variation in feeding power among different plants. There is involved only such variation as might exist between different varieties of sugar cane. While we have quite a wide variation in soil types, the lands cultivated to sugar cane involve only the lowland sections skirting the shore line of the islands. We have also the additional knowledge that under our continuous system of cropping there is an almost constant drain on the plant food nutrients and little opportunity for the natural agents such as aeration and fallowing to increase availability.

With a large number of field experiments available for studying the relation of soil analysis to soil fertility composite soil samples were collected from the experimental plots and phosphate and potash determinations made as follows:

Phosphates.

Detailed methods of analysis are obviously outside the scope of this article. Suffice it to say that the following determinations were made: total phosphate present, that soluble in concentrated nitric acid, in concentrated hydrochloric acid, in one per cent citric acid and dilute nitric acid. A total of 39 soil samples was examined, taken from 23 field experiments located on 15 plantations and 4 different islands. There was no consistent relation noted between the first three determinations and response of sugar cane to phosphate fertilization. There was some relation in the results obtained with dilute nitric but with one per cent citric there appeared a notably consistent correlation. This relation is shown in condensed form in the following table:

	Per Cent Phosphoric Acid (P_2O_5)
	In Soils Giving No Response
Average	.0493
Maximum	.3190
Minimum	.0030
	In Soils Giving Response
Average	.0017
Maximum	.0028
Minimum	.0008

A detailed study was then made of the comparative solvent properties of citric acid from which in view of the fact that all soils containing less than .0030 per cent P_2O_5 soluble in one per cent citric responded to phosphate fertilization, it was suggested that this solvent merited considerable value as a measure of available phosphates in Hawaiian soils cropped to sugar cane.

Potash.

In a set of 42 soil samples representing 14 field experiments on 13 plantations located on 4 islands, potash determinations were made as follows: total potash present, the solubility in concentrated hydrochloric acid, one per cent citric and dilute nitric acid. Here again one per cent citric was the only solvent showing any value. In those soils in which field experiments gave a response to potash the content as determined with one per cent citric varied from .009 to .023 with an average of .014 per cent. While those soils which gave no response varied from .031 to .082 per cent with an average of .054.

It is not suggested that these results give any evidence of two definite groups of phosphate or potash compounds, available and non-available but rather that they are present in different degrees of disintegration or availability. On the other hand, we do find in the specific case of coral impregnated lands larger amounts of calcium phosphates with the phosphates of iron and aluminum predominating in the normal island types. This in spite of the fact that the former are also high in iron and aluminum.

Also the general advocation of one per cent citric acid is not suggested. Neither is any ordinary potash or phosphate determination by any definite method advocated. Numerous factors are involved in the availability of any mineral constituent of the soil and in interpreting the examination of plantation soils due consideration is allowed. This latter is the direct result of a further study of related factors in the soils from these experiments.

Physical Composition.

It is a well known fact that certain soil scientists attach considerable value to the relative size of the soil particles and plant food availability recognizing the influence of various salts upon soil aggregates. In clay soils there has been noted a certain restriction of root penetration. It is, therefore, generally conceded that plants may thrive on a smaller relative amount of plant food in a sandy soil. On the other hand, the greater relative surface exposure in a clay soil is a point in favor. This is especially true of salts which are highly concentrated or fixed in the film surrounding the soil particles. A consideration of the extent to which the above factor is involved in the availability of phosphate and potash showed that with the former there was no apparent relation between physical composition and availability in our soils. On the other hand, the higher clay content of the soils giving no response to potash was significant. The color of the island soils also appears to be a factor, the yellow types being almost uniformly low in potash availability as compared to the red.

Silica.

Silica is classified in plant physiology among the so-called non-essential elements, yet sugar cane ash contains 50 to 60 per cent and Hawaiian soils are relatively high in soluble forms. The relation of silica to phosphate availability is, therefore, of interest. It was found that there was a marked relation between the solubility of silica and response to phosphate fertilization in that a greater availability of phosphate is usually associated with a higher solubility of silica and vice versa. There was also noted a close relation between the amount of phosphate assimilated, being greater where the silica was more soluble. On the other hand this factor appeared to be in no way related to the availability of potash.

Lime.

Frequent reference is noted in literature to the relation of lime and soil acidity to the availability of phosphates and potash. In a consideration of this factor results were obtained which are of no small interest. The high acidity of the soils deficient in both available potash and phosphoric acid, particularly the latter, is significant. The same was found to apply to lime, the high lime soils being higher in available forms of the above plant foods. Lime also appears to influence the assimilation of phosphate by the plant.

The application of soil analysis in determining the fertility of the sugar lands of Hawaii, interpreted upon this basis, is being applied with notably practical success, and it is suggested that similar working agreements are possible under similar conditions, that is, an intensive single cropping system confined to limited or definite areas. The interpretation is by no means infallible but in carefully considering all the related factors noted above which are associated with plant food availability and soil fertility the general application is highly successful. Field experiments are essential, of course, in establishing the analytical relationship.

Varieties at Kilauea

By J. A. Verret.

Experiment 28, 1924 Crop.
Experiment 32, 1924 Crop.

We have recently harvested two experiments at Kilauea in which Badila, D 1135, Yellow Caledonia and Yellow Tip were compared. Two crops have been harvested, one plant and one ratoon.

In these tests the Badila did not show up very well as plant, but did very well as ratoons. The ratoon crop was much better than the plant. As a result of

the good ratoon crop the total sugar per acre for the two crops produced by the Badila was more than that of any of the other varieties.

The Yellow Tip also did very well, and is now being extended on this plantation; the total area planted to it now being slightly more than 350 acres (1924 and 1925 crops).

In Experiment 28, Badila, D 1135 and Yellow Caledonia were compared. The soil of this field in which these varieties were planted is heavy and comparatively unproductive. All fertilizations were uniform to all plots and comprised reverted phosphate and sand as well as nitrogen.

The results obtained from two crops are listed as follows:

YIELD PER ACRE.

		Badila		Yellow Caledonia		D 1135	
Crop	Age	Cane	Sugar	Cane	Sugar	Cane	Sugar
Plant	22 mo.	27.9	3.30	34.1	4.00	35.7	3.55
1st Ratoon	16 mo.	37.0	3.95	27.2	2.59	29.5	2.24
Total (2 crops)...		64.9	7.25	61.3	6.59	65.2	5.79

All the cane in the plant crop was affected by rats, but the Badila suffered more in this respect than did the other varieties.

The results of Experiment 32 were similar to those of Experiment 28 in that although the Badila did not lead in the plant crop, it ratooned so well that the total for two crops was greater than that of the competing variety.

These results are reported more to show the behavior of the Badila rather than to compare with the Yellow Tip. Only one plot of Tip was harvested; the rest having been used for seed on account of the fine showing being made by this cane at Kilauea.

The Badila plant crop was badly rat eaten, while in the ratoons, the Yellow Tip suffered more from rat damage.

The results for two crops are given below:

YIELD PER ACRE

		Badila		Yellow Tip	
Crop	Age	Cane	Sugar	Cane	Sugar
Plant	22 mo.	23.7	2.48	35.8	3.58
1st Ratoon	16 mo.	45.7	5.23	37.1	3.22
Total (2 crops).		69.4	7.71	72.9	6.80

Neither Badila nor the Tips are ideal canes. Badila is too soft and brittle. It breaks easily in heavy winds and gives difficulty in milling on account of its pulpy nature.

Badila should be harvested before it gets too old. That is, we believe that two years is too long to grow Badila for best results in most places.

A serious difficulty of the Tip canes is their extreme susceptibility to mosaic and their lack of ability to withstand the disease when once contracted.

Realizing these weaknesses, we are devoting a great deal of attention to canes of this type in our breeding work, and by crossing with other varieties we hope to obtain canes more suited to our conditions. We feel that we are making progress. Our Uba crosses, especially, offer very promising material.

Variety Yields at Waipio

By J. A. Verret.

Waipio Experiment "R," 1924 Crop.

A variety test was recently taken off at Waipio in which eleven different canes were compared. The crop was 22 months old, and had received a uniform application of 300 pounds of nitrogen per acre and 100 pounds of phosphoric acid from superphosphate.

The yields obtained are listed below:

	Yield per Acre			Tons of Sugar
Variety	Cane	Q. R.	Sugar	per Acre Month
H 109	99.4	7.81	12.72	.578
H 8952	95.5	7.81	12.23	.556
H 471	82.1	7.73	10.62	.482
H 472	96.2	9.29	10.35	.470
H 5974	73.3	7.27	10.08	.458
Waipio 5	84.1	8.37	10.04	.456
H 456	91.2	9.21	9.90	.450
H 465	79.7	8.65	9.21	.418
H 5923	64.4	7.74	8.32	.378
H 5919	67.6	8.71	7.76	.352
Badila	59.7	8.34	7.15	.325

Only one cane in the entire series proved a serious competitor of H 109. One of the 1918, H 109 seedlings, H 8952, produced about the same amount of sugar as did H 109. We do not regard H 8952 as the best of the "8900" series, so these results would indicate that in that series of H 109 seedlings we have canes as good or better than H 109.

Among these we would mention H 8958, H 8965, H 89102, H 8988, and H 8906.

None of the other canes can compare with H 109. Badila was very disappointing with a low cane yield and a rather poor juice.

H 472 and H 456 produced a heavy tonnage of cane, but their juices were poor.

In contrast to these results, these two canes are attracting some attention in the Hilo district and are being tried out rather extensively.

H 456 is also being planted to some extent on Kauai where several good yields have been obtained from plant fields. An interesting thing in this connection is the fact that the juices of H 456 are very good on Kauai, being better, in some cases, than H 109 juices. H 456 is somewhat weak as a ratooner. Some fields which we have seen are rather disappointing, although others are good. Before planting this cane at all extensively, its ratooning qualities in the different districts should be determined.

The Changes in Available Plant Food During the Growth of Sugar Cane

By W. T. McGeorge and G. R. Stewart.

The object of this investigation was to study the changes in available plant food in plantation soils during the growth thereon of cane crops; to determine the comparative value of water and one per cent citric acid as a measure of these changes, and to ascertain by means of these solvents the period at which the plant makes the heaviest drain on the plant food in the soil.

Choice of Soils.

The soils chosen were Field 45, Oahu Sugar Company, Koalipea section, at an elevation of 600 feet, and at the Waipio substation. The former is a reddish brown silt loam on which a phosphate test, Experiment 6, was being conducted. This soil responded markedly to phosphate applications but gave no response to potash. The latter is a yellowish brown silty loam on which Experiment V was being conducted and which has shown no response to either potash or phosphoric acid. A brief description of these experiments, taken from the files of the agriculturists, follows:

Experiment 6, Oahu Sugar Company. This experiment was started in 1916 (1918 crop) and was carried through three crops, one plant, one long and one short ratoon. The area is located in the upper fields of the Oahu Sugar Company, on the Waianae side of the government road. So far as is known, this was a virgin field being covered with a heavy growth of lantana and other weeds. The field was plowed twice during the year previous to planting. The object of the experiment and plan are illustrated in the following figure:

The harvesting results for the three crops as given in The Hawaiian Planters' Record, Vol. XXVI, p. 164, are reproduced herewith:

Table I.

Showing Harvesting Data on Three Crops from Experiment 6, Oahu Sugar Company, in Tons Sugar per Acre.

Plots	1918	1920	1922
A	8.74	14.01	....
B	8.17	15.46	5.64
C	8.40	14.29	5.66
X	7.07	12.38	3.01

The soil studies covered the second ratoon crop (1922). The first set of samples was taken February 7, 1921, the previous crop having been harvested in November, 1920. The fertilizer for this crop was applied three days after the first set of soil samples was collected.

Experiment V, Waipio Substation. This experiment comparing the value of nitrogen, phosphoric acid and potash was started in May, 1916, and has been carried continuously since. At no time has this experiment shown more than a slight variation from the different treatments. The plan of the experiment is best illustrated in the following figure. Nitrogen was, however, increased to 300 pounds per acre for the crop to which these soil studies apply:

The harvesting results for the five crops were as follows:

TABLE II.

Showing Harvesting Data on Five Crops from Experiment V, Waipio, in Tons Sugar per Acre.

Plots	1917	1918	1919	1921	1923
A	6.20	5.80	6.08	9.31	15.24
X	5.88	5.77	5.84	9.17	14.96
B	5.86	5.76	5.82	8.64	14.57
X	6.06	5.95	6.10	8.88	15.12
C	5.52	5.99	6.17	9.25	15.04
X	5.73	5.83	5.80	8.95	14.67

The cane, during the first four crops, was Yellow Caledonia and D 1135. The 1923 crop, which the soil studies covered, was H 109 plant cane.

METHODS OF SAMPLING.

In a study such as that involved in this investigation, it is highly essential that every possible effort be made to obtain representative samples. Otherwise it is not possible to prove the slight variations, if existent. For this reason, two borings with a soil auger were made to a one foot depth in each row in every plot. For example, in Experiment 6 there were ten rows per plot and therefore a total of twenty borings was made, while, in Experiment V, with eight rows per plot, 16 borings were made. The borings from each plot were thoroughly mixed on a soil cloth and cut down to about ten pounds. This field sample was brought to the laboratory for analysis.

METHODS OF ANALYSIS.

In studying the changes in plant food during the period of these experiments, two solvents were used. In view of the fact that the principal agent of solution which the plant uses is carbon dioxide, we used, for the one solvent, water saturated with carbon dioxide. For the other solvent, one per cent citric acid was used. The methods are given in brief as follows:

1. Three hundred grams of soil without any preliminary drying was weighed into a two litre bottle, 1500 cc. of distilled water added and a stream of carbon dioxide gas passed through for 15 minutes. The bottles were then immediately stoppered and placed in an end over end shaking machine for three hours. The whole was then filtered through paper, the carbon dioxide effecting sufficient flocculation for rapid filtration and a clear filtrate. The following determinations

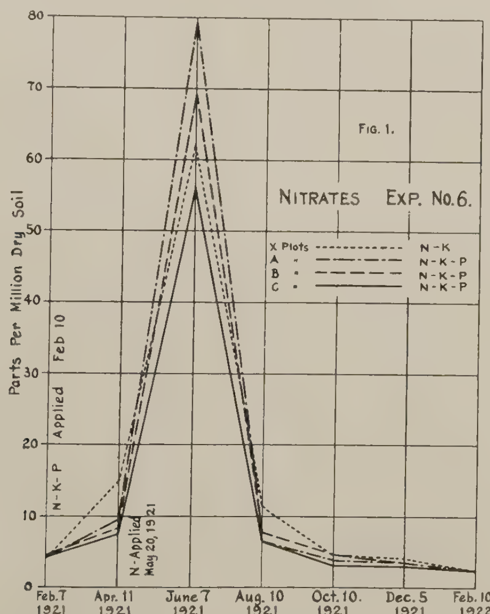
were made on this filtrate: Nitrite, nitrate, ammonia, calcium, potassium, phosphoric acid and total and non-volatile solids.

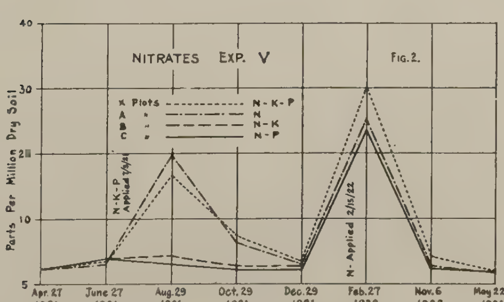
2. One hundred and fifty grams of air-dry soil was weighed into a two-litre bottle, 1500 cc. of 1 per cent citric acid added and the whole shaken in an end over end shaking machine for 6 hours. This was allowed to stand over night to settle, the supernatant liquor drawn off and filtered through paper. Moisture determinations were made on all samples and the results calculated to the water-free basis. The methods of analysis are described in Bulletins 47 and 48 of this Station.

Our results were calculated, in the water extracts, to parts per million water free soil soluble in water and per cent in water-free soil soluble in 1 per cent citric acid.

Nitrogen.

The two-month period of sampling was hardly often enough for a careful following of the rate of nitrate assimilation. The results of the analyses are shown graphically in Figures 1 and 2. The normal nitrate content of the two





soils is quite similar. In the Oahu Sugar Company soil the higher nitrate content was perceptible for approximately two months after fertilization. In the Waipio soil the results indicate perceptible amounts of nitrates to remain for a longer period, approximately three months in the first foot.

Nitrite and ammonia determinations were made at each sampling but at no time was more than a trace noted.

Of all the forms of mineral fertilizers added to the soil, nitrates are the only salts for which the soil does not possess definite fixing powers. The curves, therefore, show more rapid fluctuation and return to normal after nitrate applications.

Phosphates.

Water Soluble. The seasonable variation in water-soluble phosphoric acid was very erratic. There was no increase in water-soluble phosphoric acid with fertilization although the results indicate a higher soluble phosphate content in those plots which had received phosphate than those receiving none. On the whole, definite deductions are not possible. The high phosphate content is significant at the ripening-off stage. The results indicate the heaviest draft on phosphate in the period of 2 to 10 months' growth with a cessation during the latter stages of growth.

Citric Soluble. Using 1 per cent citric acid as a solvent, some interesting and very significant results were obtained. They clearly indicate the greater demand for phosphates during the early stages of growth, 2 to 6 months' period, and the lesser needs during the ripening-off stage.

Also the value of this solvent in determining available phosphate is strongly apparent. In both experiments, the phosphate plots were higher than those receiving none. This is more strikingly true of Experiment 6 and illustrates the influence of soil type on the solvent action of citric acid. It is suggested that this difference may be in large part due to fixation as shown in Bulletin 47. In a study of the comparative absorbing power for phosphate by these two soil types, it was found that the soil from Experiment V possessed a higher fixing power for phosphate in the presence of 1 per cent citric acid and for this reason shows a lower increase in citric soluble phosphate after fertilization.

The results attach a greater value to 1 per cent citric acid than water saturated with carbon dioxide for measuring the changes in available phosphate in the soil.

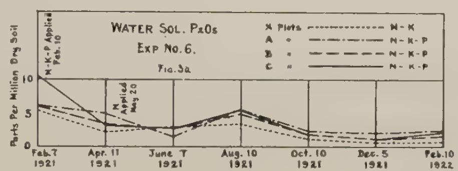
In order to determine whether this drop in citric-soluble phosphoric acid, especially in the Oahu Sugar Company soil, was due to assimilation and not to a loss from leaching or fixation in insoluble form by the soil, the following lysimeter experiments were planned. Two lysimeters were filled to a two-foot depth with soil from these two fields. Fertilizer applications were made as in the field and the lysimeters given a three-inch irrigation every two weeks. Soil samples were taken from each at two-month and four-month periods after application of fertilizer and phosphoric acid determinations were made, using 1 per cent citric acid as solvent.

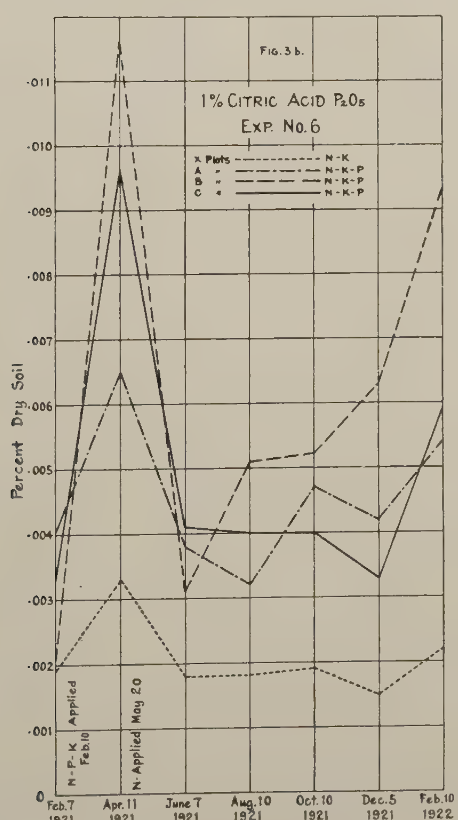
Table III.

Showing Solubility of Phosphate in Lysimeters Receiving Phosphate and No Phosphate.

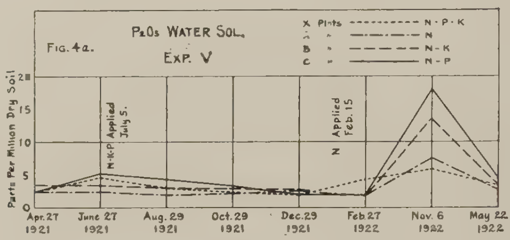
Fertilization	Soil	Two Months	Four Months
N-K	Experiment 6	.0019	.0029
N-K-P	Experiment 6	.0033	.0033
N-K	Experiment V	.0050	.0051
N-K-P	Experiment V	.0053	.0053

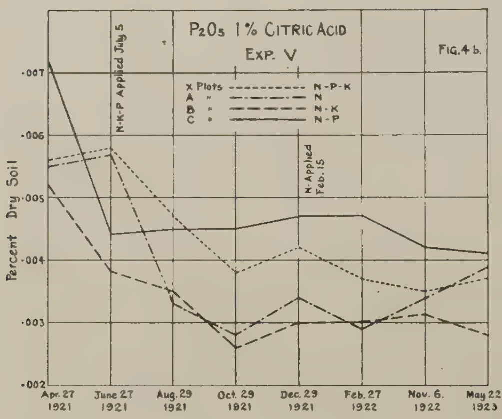
It is evident from the above that there is no loss in citric-soluble phosphate by fixation or leaching during the four months following irrigation and that the fluctuation in the curves in Figures 3a, 3b, and 4a, 4b is due to assimilation by the plant.





The greater removal of phosphate during the summer months is significant, from which there appears an association between the high growth degree months and demand for plant food. This is shown very strikingly in Experiment 6, the ratoon cane, and during the first season's growth of the plant cane in Experiment V.





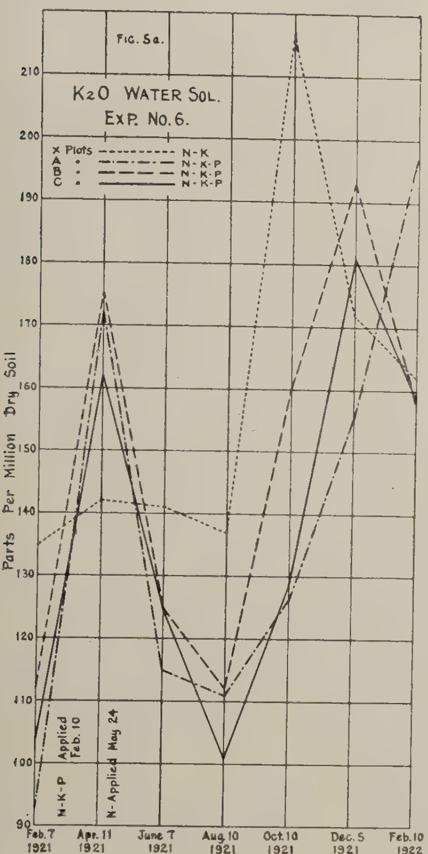
POTASH.

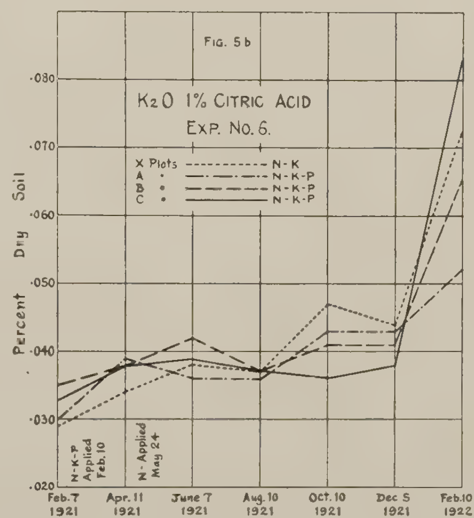
Both these soils have been shown to be amply supplied with available potash especially Experiment 6. The changes in available potash with cropping are indicated by Figs. 5a, 5b, and 6a, 6b.

Water Soluble. There was a marked increase in water-soluble potash after fertilization and a higher water-soluble potash in the plots receiving potash applications. The second to the eighth month seems to be the period at which the plant makes the heaviest drain on its potash supply. After this period there appears to be less demand. The potash-fertilized plots remain consistently higher throughout. There appears to be less demand for potash at least in the first foot of soil during the second season.

One Per Cent Citric Acid. In Experiment 6, all plots of which received potash applications, the curves for all follow the same general course. The available potash in the soil is very high and only during the fourth to sixth month is there any indication of a heavy draft on the available supply. In Experiment V, while the cane has shown no response to potash, the available supply is much lower than in the soil from Experiment 6. While the plots receiving potash applications are consistently higher than those receiving no potash, the

results are on the whole too inconsistent to allow any deductions, unless possibly the lower demand for potash during the latter stages of growth in the second season.





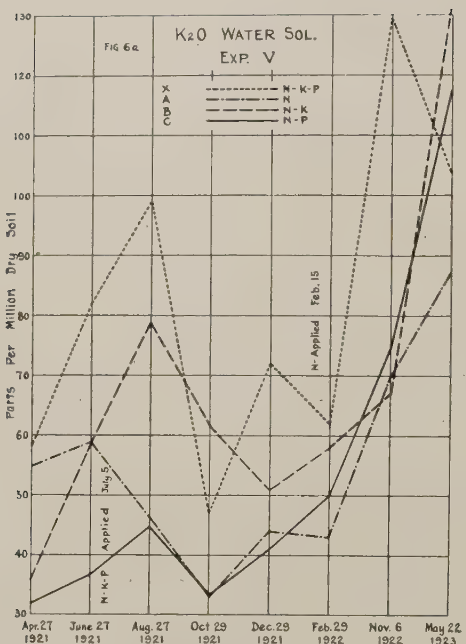
The curves in Figs. 5a, 5b, and 6a, 6b clearly show the value of citric acid for determining the differences in the available potash content of the soil. Water as a solvent is well adapted to studying the changes in potash during the growth of the plant.

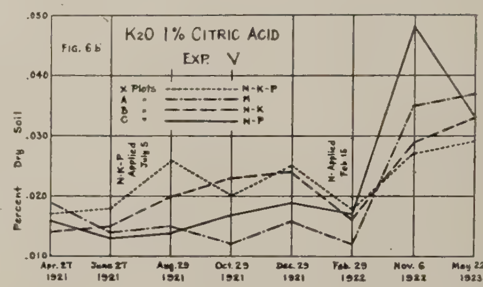
The greater removal of potash during the summer months is also significant. The amounts present in water-soluble forms decrease notably during the high growth degree period. In other words, these results plainly show the lower drain upon plant food during the slow growth winter months and the relation between plant food requirements and rate of growth. Spring dressings supply the plant food to the crop at the beginning of its period of high growth degrees.

Lime.

The changes in available calcium are shown in Figures 7a, 7b and 8a, 8b.

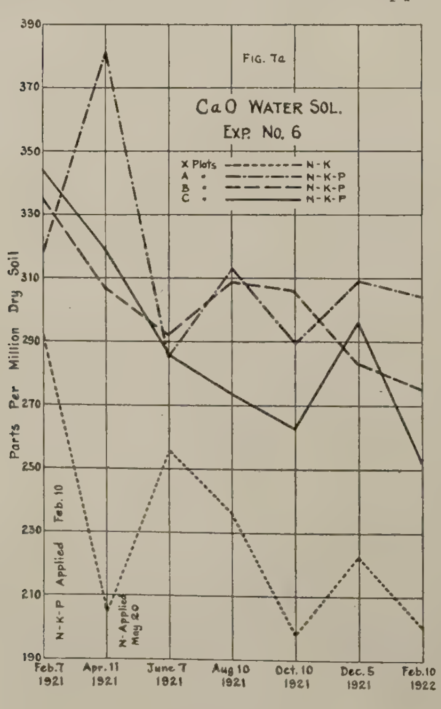
Water Soluble. There is considerable fluctuation in water-soluble lime. It is notably and consistently higher in those plots receiving phosphate applications. The greater draft on the lime supply also appears to be characteristic of the

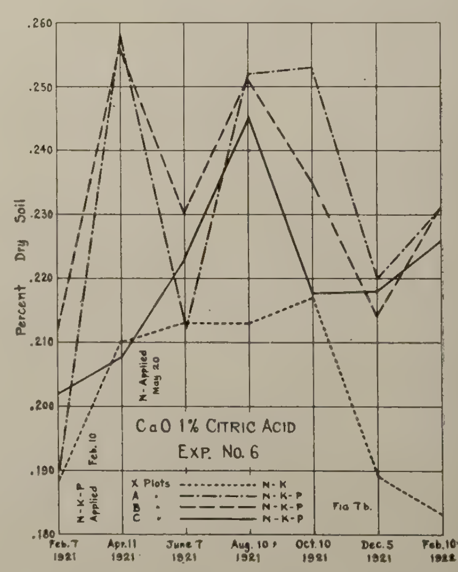




early stages of growth becoming less so during the second season. Leaching may also, however, be a factor with this element.

One Per Cent Citric Acid. The results obtained with this solvent are more consistent than in the water extract. The plots receiving phosphate are uniformly higher in available lime. There appears to be a decided decrease in lime during

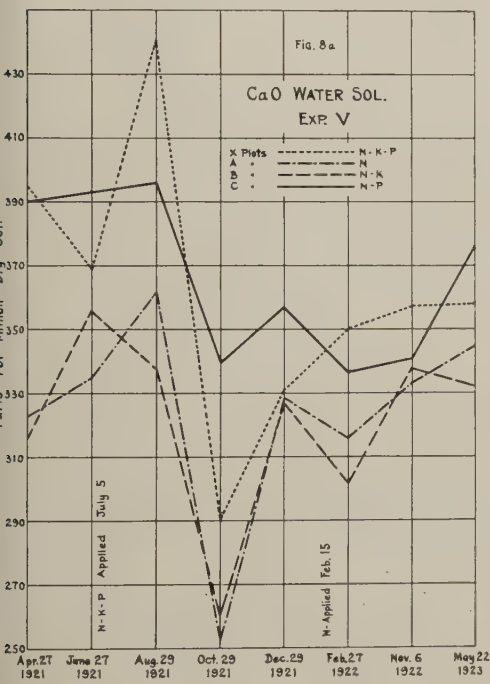


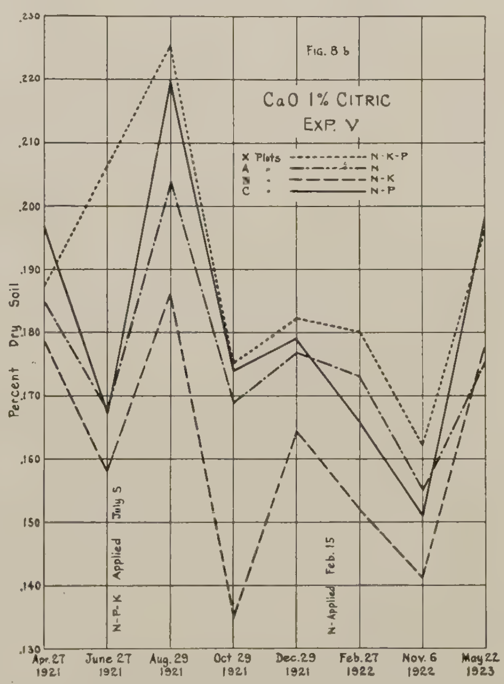


both seasons. Citric acid is better adapted to measuring the changes in available calcium.

Water-soluble Solids.

The changes in total and non-volatile solids in the water extract followed the same general trend as noted under the individual forms of plant food. An increase immediately follows the fertilizer application followed by a decrease with cropping and leaching. Water-soluble solids, therefore, decrease with cropping. In Experiment 6, the A plots receiving the heaviest applications gave the highest solids, the X plots least. Both total and non-volatile solids were highest in the Waipio soil. See Figs. 9a, 9b, 10a, 10b.

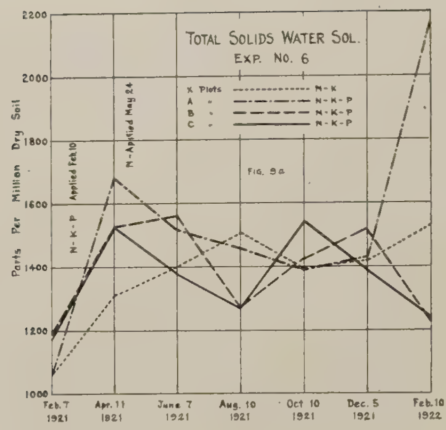




Experiment 4, Oahu Sugar Company.

At the time Experiment 6 was being harvested, an adjacent Experiment, No. 4, offered an opportunity to apply the solvent properties of 1 per cent citric acid to a series of plots receiving increasing amounts of phosphate. The plan of the field experiment is given in the following figure:

Soil samples were taken from this experiment by the system already described and the analyses using 1 per cent citric acid as a solvent are given in the following table. A gain in yield of sugar was obtained from phosphate fertilization in this experiment:



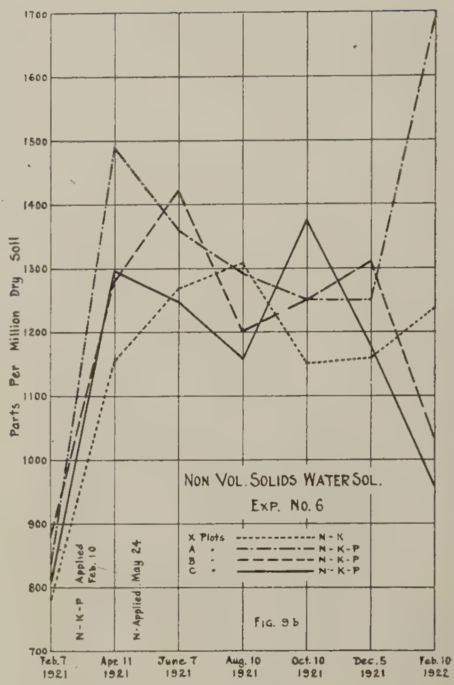
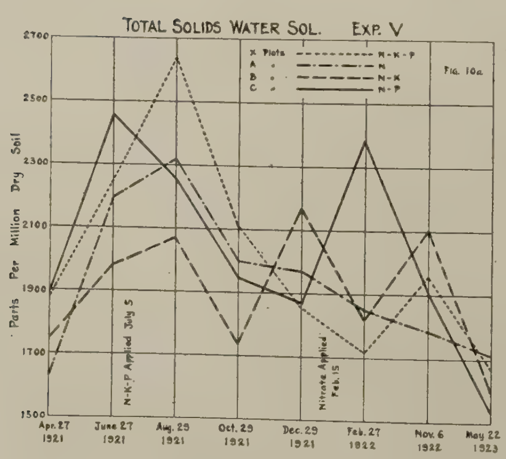
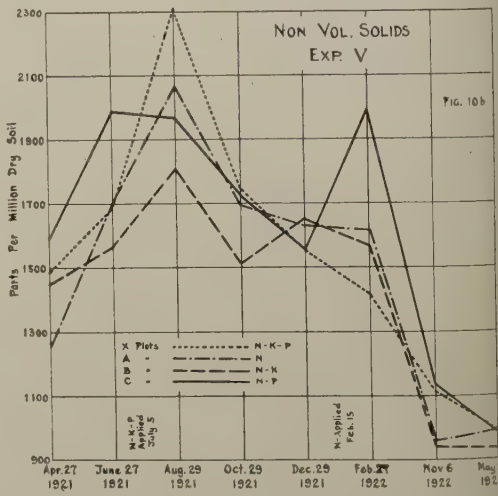


TABLE IV.

Showing Amount of Phosphate and Potash Applied in Experiment 4 and Solubility in 1 Per Cent Citric Acid as Per Cent.

Added to Soil		Per Cent in Soil			
P_2O_5	K_2O	P_2O_5	SiO_2	CaO	K_2O
0	50	.0027	.088	.148	.050
60	50	.0039	.078	.154	.051
90	50	.0048	.084	.159	.052
150	50	.0078	.094	.188	.059
180	50	.0083	.089	.200	.050

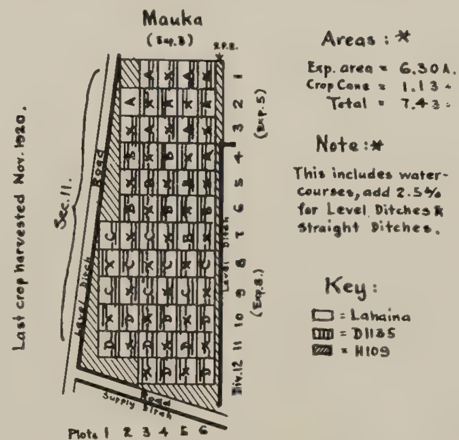




Oahu Sugar Co. Exp. 4, 1922 Crop

Field 45.

Fertilizer exp. (new land)
Phosphoric Acid requirements. Comparing 0, 60, 90, 120, 150, and 180 pounds per acre.
Cane - Lahaina & D1135, 2nd ratoons, long (½ plot of each)
Crop cane - H109, 2nd ratoons, long.
63 plots, each 1/10 acre (79.2′ x 55′) consisting of 20 single rows (or 10 double rows). Each single row = 1/200 acre. Each plot = 2 watercourses in width.



Fertilization - lbs. p.a.

Plots	No. of plots	Jan.—Feb. 1921 M.F.	Acid Phos.	Sulf. Potash	N.S.	May June '21 N.S.	Total lbs. p.a. N.	P_2O_5	K_2O
A	8	666.6	0	100	91.9	565	175	60	50
B	8	795	109	100	•	565	175	90	50
X	31	795	285	100	•	565	175	120	50
C	8	795	461	100	•	565	175	150	50
D	8	795	638	100	•	565	175	180	50
C.C.	11.3	795	285	0	•	565	175	120	•

M.F. = Mixed Fertilizer = 11% N. {7% sulf., 3% Nitrate, 1% org.} 9% P_2O_5 {Super, Bone Meal}
Acid Phosphate = 17% P_2O_5.
Sulfate Potash = 50% K_2O.
Nitrate of Soda = 15.5% N.

J.A.V.
R.S.T.
Y.K.
Jan. 1921.

While the changes during crop growth were not followed in this experiment, the data have been included to further substantiate the value of 1 per cent citric acid in measuring difference in amounts of available phosphate.

Composition of Cane Juices in Experiments 4, 6 and V.

In order to determine the effect of fertilization upon the composition of the juices, samples of crusher juice were obtained from the cane from each plot of these three field experiments and analyzed with the following results:

TABLE V.

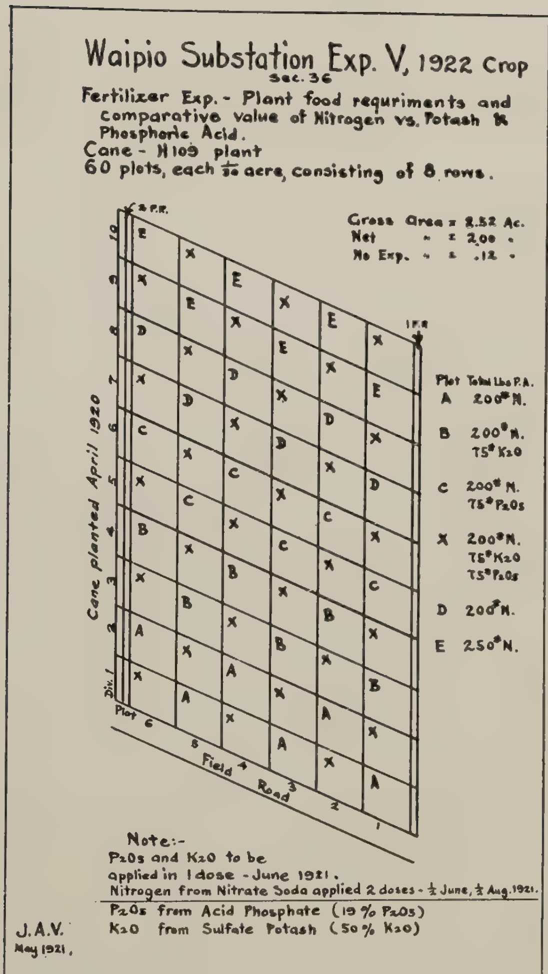
Showing Lime, Potash, Phosphoric Acid and Nitrogen Content of the Juice in Per Cent by Weight.

Experiment 4.

Pounds per Acre Fertilizer Applied			Per Cent In Juice By Weight			
N	P_2O_5	K_2O	CaO	P_2O_5	K_2O	N
175	0	50	.021	.0115	.177	.076
175	60	50	.028	.0138	.189	.050
175	90	50	.024	.0112	.226	.055
175	150	50	.023	.0139	.214	.054
175	180	50	.024	.0139	.222	.054
			Experiment 6.			
175	0	50	.026	.0082	.122	.077
175	180	50	.026	.0109	.140	.039
175	90	50	.021	.0107	.136	.032
175	90	50	.023	.0090	.111	.036
			Experiment V.			
300	0	0	.014	.0295	.122	
300	0	75	.012	.0267	.141	
300	75	0	.013	.0267	.120	
300	75	75	.013	.0284	.131	

It is significant that the juice from Experiment V, where no response was obtained, is notably higher in P_2O_5 than that from Experiments 4 and 6, both of which responded to phosphate fertilization. Strangely enough, there is little or no increase in the phosphate content of the juice brought about by phosphate fertilization. This is true in spite of the fact that a decided increase in sugar and cane yield was obtained in both. It indicates that factors other than the available phosphate present in the soil are involved in the assimilation of phosphate by the cane. While phosphate fertilization, where this element is deficient, may produce an increased yield and accompanying this an increase in total amount of phosphate assimilated, there is little or no increase in the actual phosphate concentration of the juice as is characteristic of the juice from plants grown on soils naturally high in available phosphate. Other investigations already reported from this laboratory have shown that the concentration of phosphate in the juice is related to the soil reaction and the forms of silica and lime present in the soil. There appears to be a slightly higher assimilation of phosphate by the D 1135 in Experiment 4 than the H 109 from the adjacent Experiment 6.

There is a greater concentration of lime in the juice from Experiments 4 and 6 than that from V. This is the direct opposite to the solubility in the soils using water as a solvent but agrees with the relative solubility in 1 per cent citric acid. It should be mentioned that the soil from Experiments 4 and 6 is highly manganiferous. Pineapple plants grown on such soil types suffer a serious nutritional disturbance from an excessive assimilation of lime. It is possible



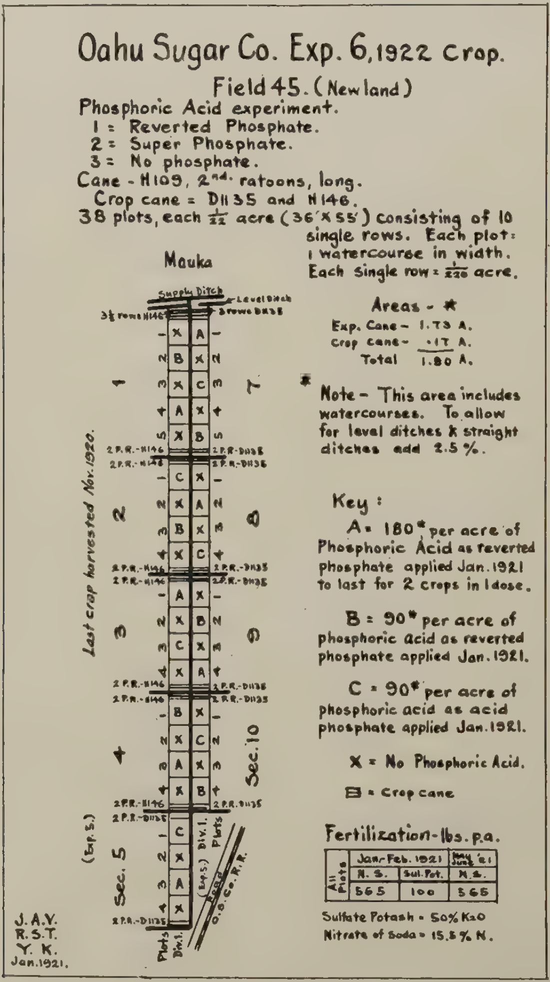
that a higher assimilation of lime by the cane on such soil types may be a factor in the above results. The cane having a higher lime requirement shows no chlorosis as does the pineapple.

In Experiments 4 and 6 all plots received the same amount of potash. The fields were adjacent fields and neither had given response to potash fertilization. It is notable, however, that the juice from Experiment 6 is much lower in potash. The cane grown in Experiment 4 was D 1135 and that in Experiment 6, H 109, which suggests a difference in feeding habits between the two varieties.

Conclusions.

The preceding studies bring out several points which have an important bearing upon the chemical work used to interpret soil fertility changes. Work carried on with mainland soils has indicated that water was possibly the most universally applicable solvent to use in following the changes in plant nutrients which occur during cropping. This will not hold for Hawaiian soils. Practically

all our soils contain notable quantities of the hydrated oxides of iron and aluminum. These colloidal complexes have notable fixing powers for practically all the plant nutrients. Even nitrates were found to be appreciably retained by soil columns in experiments previously published by one of the writers (1). It is doubtful if accurate determinations of water-soluble phosphates can be made in these soils even where a solution saturated with carbon dioxide is used as a solvent.



A dilute solution of citric acid, such as the one per cent strength employed in Dyer's method, appears to be best suited to study the changes in nutrients in the highly colloidal Hawaiian soils. Some fixation has even been shown (2) to take place from this solvent but it appears to be the best solution for determinations of the more available potash and phosphates. This conclusion agrees with the results obtained in two other investigations (2 and 3) carried on by one of the writers.

Summary.

1. Determinations of changes in plant nutrients in the soil using water saturated with carbon dioxide showed that water was only suitable as a solvent for soil nitrates and to a lesser extent for potash.

2. One per cent citric acid was preferable for determinations of the effect of cropping upon lime, phosphates and potash.

3. Phosphoric acid was taken up in largest amount during the early stages of growth, 2 to 6 months with the ratoon crop which was under observation.

4. Potash was also taken from the soil in greatest amounts at an early period, namely, from the second to the eighth month of growth.

5. Lime was largely taken up during the first season, the demand for lime decreasing during the second season.

6. Determinations were made of the potash, phosphoric acid and lime in the juices of the cane harvested from two phosphate tests at Oahu Plantation and one phosphate and potash test at Waipio substation. The experiment at Oahu gave a response to phosphates but there was no appreciable increase in the per cent phosphate present in the juice from the fertilized plots. Potash gave no response in either experiment and the per cent in the juice was not increased by potash fertilization.

References.

1. Absorption and Interaction of Fertilizer Salts and Hawaiian Soils. The Hawaiian Planters' Record, Vol. 26, p. 186.

2. A Study of the Phosphates in the Island Sugar Lands. Bul. 47, Agric. and Chem. Series, Exp. Sta. H. S. P. A.

3. The Availability of Potash in Hawaiian Soils. Bul. 48, Agric. and Chem. Series, Exp. Sta. H. S. P. A.

Bacterial Red Stripe Disease of Tip Canes*

By H. Atherton Lee and W. C. Jennings.

There is an old saying that an ounce of prevention is worth a pound of cure. There is no instance where this is more applicable than in the control of cane diseases; this is so fundamentally true that for each plantation, each district, and for the Territory as a whole, the first measure to be adopted for the control of cane diseases should be exclusion of new troubles.

A new cane disease, called red stripe, is occurring in the Kohala district on Yellow Tip, Striped Tip, and Red Tip canes. This circular is prepared for the purpose of advising plantations growing Tip canes in the Hamakua and Hilo districts on Hawaii, and those on Kauai and the other islands, of the appearance

* Originally published as Circular No. 42.

and nature of this trouble. With this information available, exclusion of red stripe disease from the plantations and districts not yet affected can be readily maintained.

Red stripe, being restricted to Tip canes, the total losses to the Territory resulting from it would not be large. However, losses on Tip canes from the disease may be expected to run from one to five per cent of the production per acre, possibly higher. The loss, even if less than one per cent, should be prevented, since it can be avoided at the present time with no cost to the plantations. It is good business to avoid losses from disease, no matter how small, for such losses are repeated annually. This is especially true when no investment is required in such prevention. Care in the prevention of this trouble will save money.

Appearance of the Disease.

Red stripe disease is most noteworthy, and probably is of a more serious nature on young cane, from six inches to three feet high, than on old, well-formed cane. It is easily identified by the long, narrow, dark-red, longitudinal streaks on the cane leaves. These streaks usually start midway between the tip of the leaf and its juncture with the leaf sheath, at the point where the bend in the leaves of Tip canes takes place. The first indication of the disease is a watery darkened streak, not yet red, but still green, which spreads longitudinally up and down the leaf. This watery, dark-green streak gradually becomes bright red in color.

Such streaks are most commonly seen first near the midrib, then other longitudinal streaks usually follow farther from the midrib. In a few cases, the streaks may be seen along the edges of the leaves, but this is quite uncommon. Frequently the lower side of the midrib shows the longitudinal streaks, but seldom the upper side. The streaks are narrow, usually from ½ to 1 millimeter wide (1/50 to 1/25 inch); occasionally as wide as 2 millimeters, and sometimes coalescing, as shown in Plate 1, to give the appearance of a broad band 4 to 5 millimeters in width (3/16 to 1/4 inch). The appearance of the disease is better understood from the photographs, Plates 1, 2, and 3, than from a written description.

These red longitudinal streaks, or the watery dark-greenish streaks which precede the red streaks, seldom pass the juncture of the leaf blade with the leaf sheath; in a few instances the lesions run down into the leaf sheaths, but only in very severe cases.

Infection does not seem to take place on the older leaves, but is seen more commonly on the middle-aged leaves. In severe cases, the young leaves, when still unrolled, are infected. Following heavy infection of such central leaves, a top rot of the cane frequently results, causing lalas to be put out and probably a lowering of the quality of the cane juices.

Leaves of cane approaching maturity are not as severely affected as the leaves on the younger cane; the red streaks are not as abundant on such older canes. In a few cases, however, when the red stripe leads to top rot, red streaks may be seen running down into the cane when it is split open; this probably also results in a lowering of the quality of the juices.

Plate 1.—Showing the dark-red, longitudinal streaks, in this instance on leaves of Striped Tip cane. The leaf on the right shows the streaks coalesced to such an extent that the green, actively-functioning part of the leaf is entirely destroyed.

Young cane shoots which are shaded by the older cane are usually more severely affected and frequently die out entirely from the disease.

Red stripe is usually much more severe on ratoons. Young shoots in ratoon fields frequently develop top rot when but a foot or two high and are killed back; this in some instances results in thinning out the stools to a considerable extent. This thinning out of young shoots in the stools is shown in Plate 3. Apparently young, active, vigorously growing leaf tissue is more susceptible than slow-growing, hardened leaf material.

Varieties Affected.

Red stripe occurs in commercial plantings on Yellow Tip, Striped Tip, and Red Tip. A number of the native canes are also affected, some of them more seriously than the Tip canes. H 109 has never been observed to be affected. Rows of D 1135, Badila, and Yellow Caledonia, surrounded on all sides by affected Tip canes, have also shown a very high degree of resistance, although small but definite red stripe lesions have been observed in a single instance each on D 1135 and Yellow Caledonia. Cuttings of these canes, therefore, although resistant, would be a possible means of transporting the disease into uninfected districts.

Cause of the Disease.

Examination under the microscope shows the red streaks to consist of discolored, reddish-brown cells from which the chlorophyl bodies have disappeared. The cell walls of such browned tissues are greatly thickened. From such browned tissues frequently great masses of bacteria ooze out. Examination of cells apparently still normal, lying close to the discolored tissues, shows the presence of motile bacteria; these have been observed in the tracheal vessels and in the cells forming the sheath surrounding the vascular bundles.

Isolations have yielded bacteria which in preliminary studies have reproduced the disease on inoculation, while inoculations without these bacteria have remained healthy. The proof is very definite that the disease is caused by bacteria. The studies on this organism are progressing and it will be possible to give a more detailed account of the isolation and inoculation work as well as the description of the causal organism within a short time.

Dissemination.

The observation has frequently been made in Kohala, that red stripe disease is usually slightly more general on the windward side of the field. It would be natural to expect such a bacterial disease as this to be disseminated to some extent by the wind, and this observation in a way corroborates this expectation. Other bacterial diseases are favored by wet weather; either rain or heavy dews forming a moist, dripping condition. Such a moist, dripping condition in the cane fields probably also favors the dissemination of red stripe.

On many of the watery-appearing, longitudinal stripes of affected cane, evidences of chewing insects were observed; such chewing is shown in the photograph in Plate 2. Apparently the juices of infected cells or tissues are peculiar in their odor or flavor and are attractive to such chewing insects. This, of course,

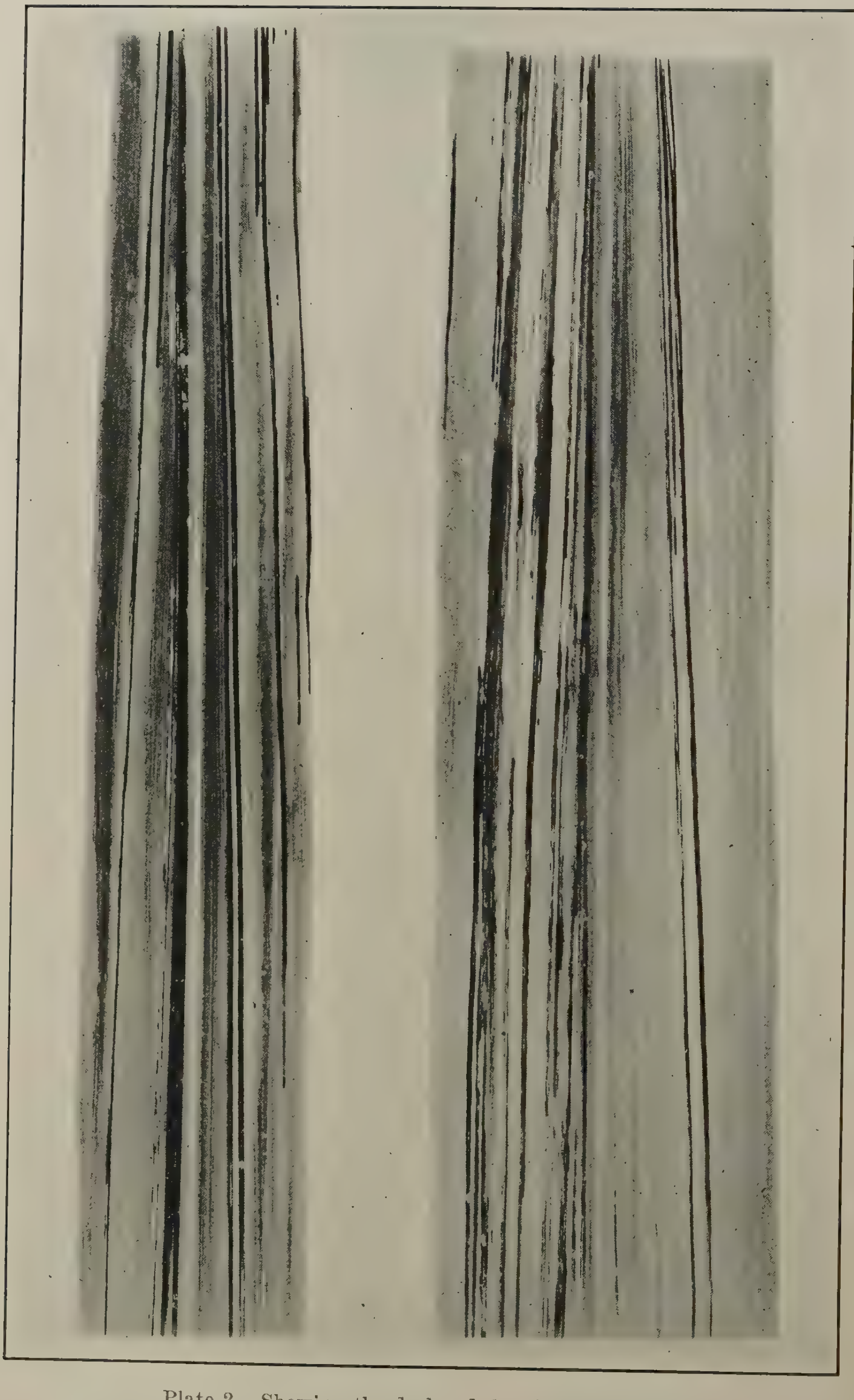


Plate 2.—Showing the dark-red, longitudinal streaks also on leaves of Striped Tip cane. Small areas can be seen where insects have been chewing in the watery streaks. This photograph shows the upper surface of the leaf, while Plate 1 shows the lower surfaces.

is immediately suggestive of the spread of the disease by chewing insects in addition to the agency of the wind and rain. Such a condition will be very difficult to combat in preventing the spread of infection in districts where it is already established.

There is also evidence to indicate that the disease is transmitted occasionally by cuttings.

Control of the Disease.

For the plantations growing Tip canes on Kauai, and in the Hamakua, Hilo, and Kau districts of Hawaii, the cheapest control of the disease is exclusion. Exclusion involves no expense whatsoever, but necessitates discretion and the exertion of a little care on the part of individuals visiting the Kohala district.

Cane knives or pocket knives used in cutting cane of any nature in Kohala should be disinfected before being used in any other district. A solution of mercuric bichloride 1 to 1000, or a 10 per cent formalin solution, or a 2 per cent lysol or cresol would be satisfactory disinfectants for such use. One visiting Kohala and handling diseased canes should disinfect hands and arms and avoid contact of clothes, shoes, or hats with healthy cane outside of the district, until they have been laundered, washed, or disinfected in some way.

Although rather an extreme precaution, it is nevertheless advisable to avoid driving a car from infected fields into plantation roads in uninfected districts where the parts of the car would come into contact with the leaves or other parts of Tip canes. Field implements from Kohala should not be used on plantations having Tip canes, unless they have been disinfected.

No cane cuttings nor any parts of the cane or grasses of any nature should be carried from Kohala into uninfected districts. Related grasses, especially regarded with suspicion, are such plants as sorghum, broom corn, corn, Elephant grass, Sudan grass, etc.

A quarantine has been enacted by the Board of Agriculture and Forestry of the Territorial Government, penalizing, with a fine of five hundred dollars, the movement of any cane or any parts of cane or grasses from the Kohala district.

In the event of the disease breaking out through the neglect of proper precautions by individuals, plantations should be prepared to eradicate affected cane up to an area of five acres or even more. Such a measure would involve less loss than would result from the spread of red stripe throughout all the districts growing Tip canes.

In the Kohala district, ultimate control of the disease will be probable by the use of resistant Kohala seedling varieties of Tip and D 1135 parentage. With the determination of the causal organism, the susceptibility or resistance of these Kohala seedlings can be readily determined. There is reason to believe that among the Kohala seedlings which do well at high elevations, one or several will be found which are resistant. In the meantime, red stripe may be avoided and minimized, to some degree at least, by discretion in planting and fertilizing practices.

As an instance, it is becoming generally accepted that regardless of disease conditions, middle and mauka land fields in Kohala should be harvested and planted early, in order to give the young plant cane and ratoons the advantage of

Plate 3.—A ratoon field of Striped Tip cane at Kohala showing the leaves of the smaller shoots withered and killed out, and the resulting thinned-out appearance of the stools.

the best growing months in which to become established before cold weather. Bearing in mind that the cane is affected most severely when it is young, from 6 inches to 4 feet in height, anything which can be done to push the cane past this stage before the wet, cold weather of winter sets in, will also aid in minimizing the disease. Thus, where plantation conditions render it possible, early planting is especially desirable in the case of fields which have been infected with red stripe disease. If the cane is started before June, at the latest, by the time

the wet weather arrives, it has grown past the stage in which it is the most susceptible.

The proper timing of fertilizer applications will also aid in avoiding the disease. When the cane is planted early, applications of nitrogen shortly after planting will push the cane past the dangerous age by the time the wet weather favorable for infection arrives. With winter weather over, fertilizer applications will also be an aid in recovering lost growth due to the disease, if drought conditions do not prevail. Purely from the standpoint of the control of the disease succulent growth should not be forced out just prior to the winter season by fertilizers. Since, however, the success of fertilizers depends upon adequate moisture, it is hardly feasible in the Kohala district to withhold fertilizers on account of this disease, excepting possibly in rare cases of severe infection, where extreme measures might be used.

The inoculation of the Kohala seedlings to test for resistance and the gradual substitution of the resistant varieties will be, however, the most effective and satisfactory means of combating red stripe in Kohala. The prevention of the spread of the disease into Hamakua and Hilo and the other islands is the most economical means of combating red stripe outside of Kohala.

Chasing Bubbles in a Boiler*

An Outline of Where Steam Forms in a Boiler and the Path of the Water Circulation—Description of a Glass Model Boiler Used in the Study.

There are several hundred thousand engineers in charge of boiler plants who pride themselves in knowing all about boilers. If asked the question, "What is the water circulation in a boiler?" each and every one would have a very definite opinion, although the answers of any ten would not agree. Ask yourself this question and see how near your answer approaches the real facts as here outlined.

The wide divergence in opinion as well as the lack of actual information possessed by even those conceded to be the "knowing ones" in boiler design, was strikingly brought out in a contest instituted by the E. Keeler Company. Under the terms of the contest the engineer who described correctly the circulation in the horizontal return-tubular boiler was to be awarded a prize. Hundreds of engineers and engineering associations entered the contest, and the variety in answers almost equaled the number of contestants. A local of the National Association of Stationary Engineers won the prize, the answer, which was a composite of its members' opinions, being practically correct. Incidentally, some of the members actually constructed a glass model of the boiler before submitting their answer, and so were playing a "sure shot."

The widely differing opinions are not to be wondered at for the reason that whenever this subject has been touched upon by technical journals, a correct circulation has never been shown, and it may be mentioned that in recent text-books the circulation in return-tubular boilers is described in accordance with the previously accepted idea on the subject; that is, that the circulation path is upward

* Power, Vol. 59, No. 8.

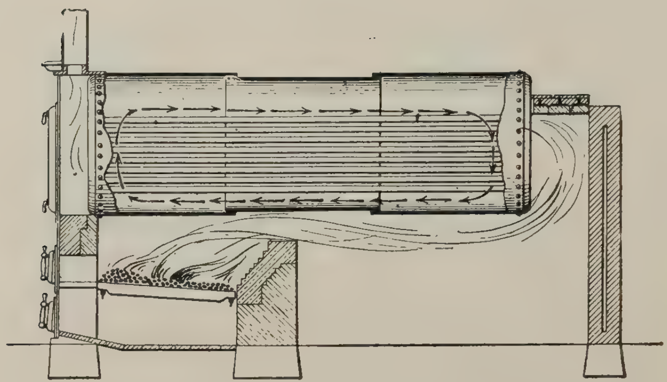


Fig. 1. Popular idea of how water circulates in a boiler.

at the front head, backward on the surface to the rear head, then downward at the rear, with a distinct forward circulation along the shell at the bottom, as shown in Fig. 1. After several years' experimental work, A. C. Lippincott, of the E. Keeler Co., succeeded in constructing a working glass model for demonstrating purposes before steam engineering organizations. The dimensions are to all intents in proportion to those of an actual boiler, and it is therefore possible to determine the circulation in a boiler of standard capacity.

Examination of the glass model shows that the water and steam mixture rises up along the front head, as indicated in Fig. 2, at a high velocity, and after releasing the steam bubbles, the water moves toward the rear until it reaches a point a little beyond the center of the boiler, whereupon it drops downward. Upon reaching the lower part of the boiler, the main part of the stream turns toward the boiler front, while a part flows toward the rear. There is a secondary

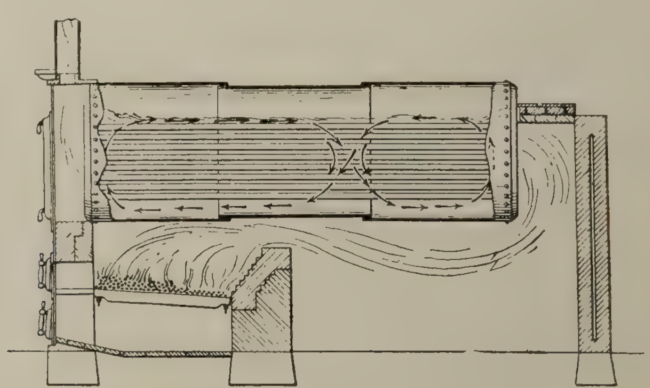
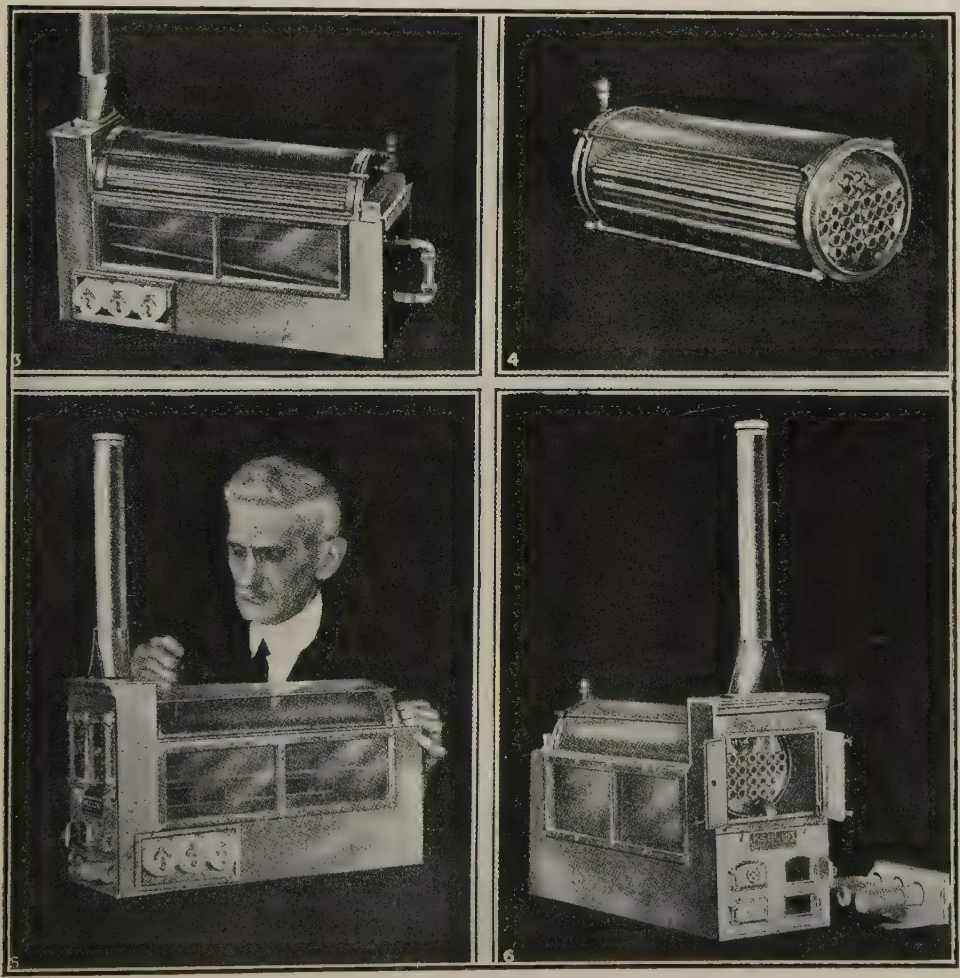


Fig. 2. Actual circulation as determined by study of a model boiler.

steaming zone at the rear head, causing an upward flow, the current then flowing toward the front and downward, making a loop. These two actions cause the circulation of the water to be in the form of a figure 8 placed horizontally thus, ∞. The two streams interconnect as indicated in Fig. 2, but the major part of the steam bubbles are formed in the immediate vicinity of the front head.

Tea leaves placed in the boiler show that at the middle of the boiler, where the two streams cross, the circulation between any pair of tubes may be upward at one time, followed by a downward motion. The leaves also reveal that, contrary to the popular belief, there is no area of quietude in the boiler; leaves placed just above the blowoff are finally thrown into circulation. Likewise the argument that sediment will deposit on the belly of the boiler just above the bridge wall apparently has no basis, for the velocity of the water at this point is very high.

Strangest of the deductions to be made is that the water has the greatest ebullition along the front head. The front tube sheet is the coldest part of the boiler, much lower in temperature than is the rear tube sheet. It seems that the water immediately above the furnace absorbs heat rapidly and begins boiling. The upward circulation causes a flow of water from the rear, and the velocity set up is great enough to carry this water forward until it strikes the front sheet, whereupon the flow is upward between the tubes, the circulation shifting the natural upward path from being directly over the fire, to the front tube sheet. This is



Figs. 3 to 6. Views of model boiler.

so violent that the water is driven up against the top shell, incidentally showing that the steam and safety outlets should not be located well forward.

The circulation at the rear head is what is to be expected, since this part of the boiler is at a fairly high temperature. It may be stated with considerable accuracy that the greater part of the heat of combustion is absorbed by the boiler shell and that the gas temperature at the rear tube sheet is far below the furnace temperature.

An interesting experiment was conducted on the model boiler to determine the value of an external circulation tube placed in the furnace. For many years an occasional boiler has been fitted out with one or more "drop tubes" connected to the rear and front heads of the boiler by suitable fittings and passing through the furnace. The belief was that this pipe increased the boiler efficiency as well as the circulation. The model was equipped with one drop tube, as shown in Fig. 3, with a short section of gage glass in the circuit, and while no efficiency tests were run, it is significant that the pipe did lessen the time required to raise steam by 50 per cent. When steaming, the circulation was increased to a marked extent.

The Lippincott glass model boiler is shown in the illustrations on this page. The shell of the boiler, Fig. 4, is of pyrex glass, the heads of brass, while the tubes are of brass held into the front head by locknuts. External through bolts hold the heads, relieving the tube ends of much of the head pressure. The boiler setting or casing is of planished sheet aluminum, well insulated, and the front frame and doors are of cast aluminum, as is also the chimney. Three electric resistance coils supply the necessary heat, these being preferred to a gas flame. The type of heat apparatus does not alter the path of circulation to any extent, even when the flames of two gasoline torches are thrown into the furnace and against the rear "wall."

[W. E. S.]

The Performance Records of Some Individual Sugar Cane Stools

By A. D. SHAMEL.*

Object of the Study: This study was planned in 1922 for the purpose of (1) comparing the production of H 109 sugar cane grown in pukas with that

* In submitting this paper Mr. Shamel wrote:

"I recommend that this manuscript be published by the Experiment Station as a matter of record and for the use of those who are engaged in bud selection studies with sugar cane.

"I consider this study to be of fundamental importance in that it indicates the practicability of single-eye three-joint cuttings spaced five feet apart each way for individual stool study as a basis for intelligent selection work.

"The information secured in this study has enabled us to arrive at a satisfactory and intelligent conclusion as to methods for starting and growing individual stools of sugar cane for performance record study."

planted in trenches, (2) determining the practicability of using single-eye three-joint cuttings spaced five feet apart each way for experimental field work in general and bud selection studies in particular, (3) studying the comparative yields and habits of growth of a few of the apparently higher yielding progenies with the characteristics of a few of the apparently lower yielding ones, (4) securing information as to methods for carrying on systematic progeny tests under carefully controlled conditions for scientific study and observation, (5) making observations on the growth of the Uba variety as compared with H 109 where grown under similar conditions.

Location of the Experimental Plot: The experimental plot is located on the Experiment Station grounds in the west section of Makiki Field 7 and consists of a small area in the extreme northwest corner of this field.

Arrangement of the Experimental Plot: The plot was laid out with 9 rows of pukas beginning on the west side of the plot, followed by 4 rows of trenches and with an additional line of pukas on the east side as shown in the accompanying Map 1. The rows run north and south. The last line of pukas on the east side is not fully comparative with the remainder of the lines and the yields of cane in this row have not been used in calculating the comparative data as shown in the tables given in this report and are presented in a separate table of yields.

Puka and Trench Arrangement: The pukas are holes about 1½ feet square, 1½ feet deep and spaced approximately 5 feet from center to center in rows 5 feet apart. The trenches are the usual plant rows, 5 feet apart and with trenches in the bottom about 1½ feet deep in which the cuttings were spaced approximately 5 feet apart.

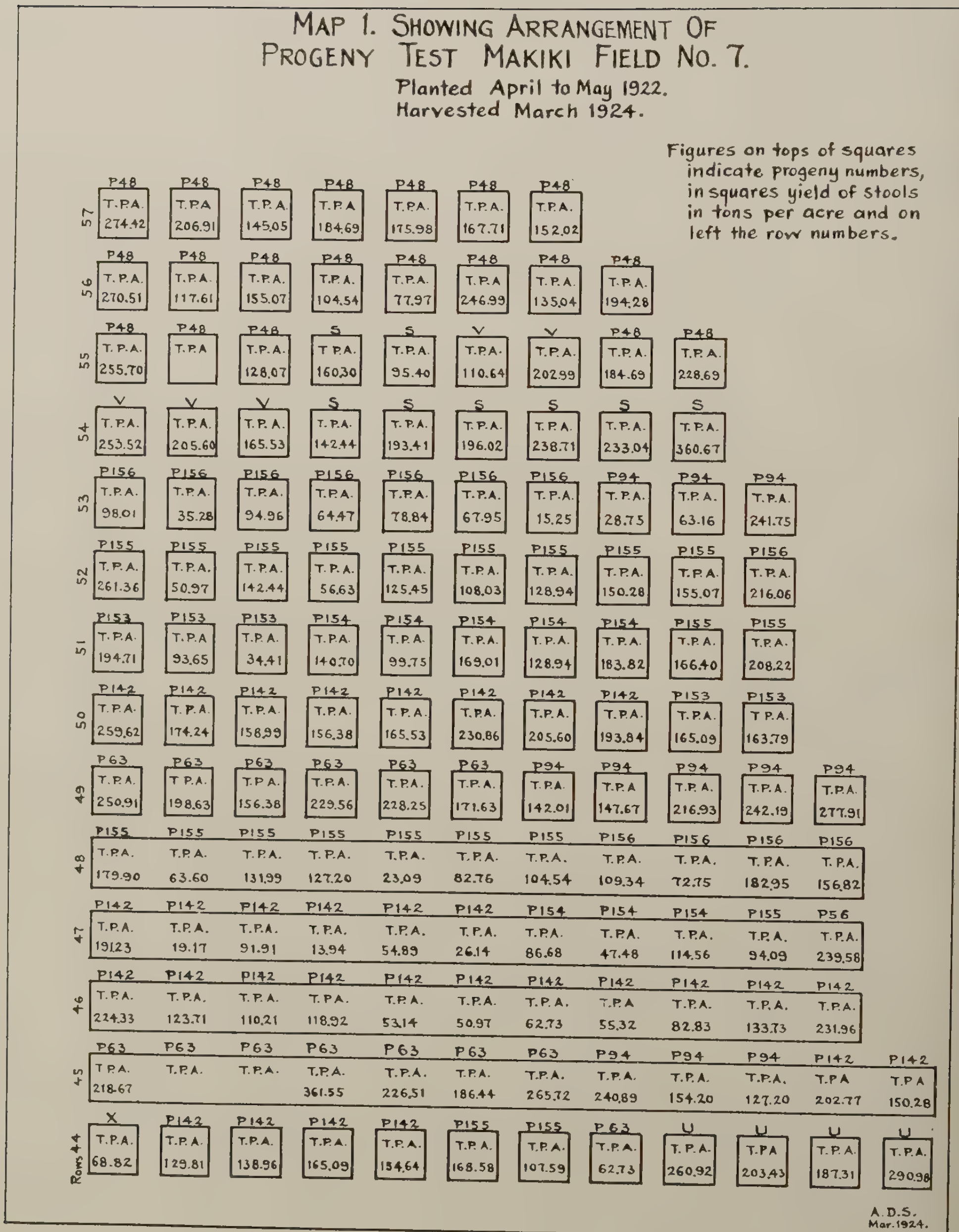
Fertilization: The fertilization of the cane plants in this plot consisted of regular applications of a mixture of nitrate of soda and ammonium sulphate applied at monthly intervals beginning June 12, 1922, and ending September 12, 1923, 1924, making a total application of nitrogen at the rate of about 100 pounds per acre per month. At the time of planting, manure consisting of a mixture of stable manure and trash was mixed with dirt in the bottom of the pukas and trenches at the rate of about 9 bucketsful per stool.*

Irrigation: The irrigation of the cane in this plot was done with a garden hose and about 4 inches of water was applied at semi-weekly intervals from the time the cuttings were planted in April, 1922, and continued until December, 1923.

Handling the Plant Material: The plant material consisted of single-eye three-joint cuttings secured from eight of the H 109 progenies then growing at Waipio, two selected stools of H 109 from the plantation of the Oahu Sugar Company, 4 cuttings of Uba and one of the Lyman seedling. The cane stalks used for the plant material were about one year old. The seed pieces were cut with three joints, the two end eyes being gouged out with a knife leaving one good eye to each cutting.

Planting the Cuttings: The single-eye three-joint cuttings were first planted in small shallow boxes, those planted in rows 54 to 57 inclusive being started March 3, 1922, and those planted in rows 45 to 53 inclusive started April 8, 1922.

* The test was designed in part as an experiment in forced growth on widely spaced plants from single eyes, and was suggested by work of the Cuban Experiment Station along these lines.



The cuttings of H 109 and Lyman seedling for planting in row 44 were started in boxes during April, 1922, while the Uba cuttings were started on June 30, 1922. Good strong seed pieces were used in all cases.

Transplanting the Cuttings: The cuttings were grown about one month in the germinating boxes and then transplanted to the field plot. The transplanting was done during April, May and June, 1922, with the exception of the Uba cuttings which were transplanted July 11, 1922.

Growth Measurements: Systematic growth measurements were carried on with stalks of selected stools in order to show the rate of growth of the plants during the different seasons throughout the entire course of this experiment.

Cut-out Stools: Of the total 129 stools planted for comparative study, two H 109 stools, 47-3 and 55-2, were cut out in June, 1923, for new progeny tests and one H 109 stool, 45-3, was taken out on account of mosaic disease, leaving a total of 126 stools in addition to those in the outside row on the east side of the plot.

Parentage of the Progenies: The progenies used in this study were designated by numbers and symbols as follows: P 48, S, V, P 156, P 153, P 94, P 155, 154, P 142, P 63, X, and V. Those with P (abbreviation of progeny) followed by numerals designated the Waipio progenies, S and V the two selected stools from Oahu Sugar Company plantation, X the Lyman seedling,* and U the Uba variety.

The parent Oahu Sugar Company stools were selected on account of their development of a large number of uniformly good stalks indicating inherently desirable characteristics. The Lyman seedling stool was grown from a cutting of a stool of this variety grown on the Olaa plantation. The Uba cuttings were secured from a stool of this variety grown at Makiki.

Causes of Reduced Yield: Considerable loss of crop, including dead and broken, stolen, rat-eaten, borer- and termite-injured stalks, blown over and uprooted stools, which developed in this plot might have been avoided in part at least if the plants had been harvested at the end of a sixteen or eighteen month period. However, it was deemed advisable to grow the plants for two years in order to ascertain the facts concerning the rate of growth, habit of growth and eye development of the plants during this period. The loss from the causes noted above is estimated to have been more than 25 per cent of the total final weight of crop.

Harvesting: The harvest of the cane plants in the plot was begun March 6, and was finished March 20, 1924.

Each stool was harvested separately. In a few instances each individual stalk of the stool was cut, weighed, measured and its performance record data recorded. In most cases, however, the second season stalks in each stool were cut first and the data secured from their study recorded after which the first season stalks were harvested and studied with a systematic record of some of their characteristics. The plan of harvest procedure was as follows:

(1) The second season stalks were cut and any dead or stolen ones counted. The number of healthy stalks was determined as well as their average length, their total weight, the number showing evidence of borer injury and damage from breaking or mechanical injury and the number of tasseled stalks. Special notes were made where necessary concerning unusual conditions, e.g., rat or termite damage, lala development, dead tops and as to the uniformity of stalks in particularly good stools.

(2) The first season stalks were cut and the number of dead or stolen stalks recorded. The number of healthy first season stalks was then counted, their average length recorded together with their weight, the number of stalks attacked

* This variety was cut for seed in 1923, so the data concerning it may be disregarded.

by borers and those broken or tasseled. Similar notes to those secured from second stalks were obtained from first season stalks as opportunity offered. The second and first season stalks were kept separate until the performance record data were secured.

(3) From a few apparently good stools in all of the progenies, composite samples of stalks from both the second and first season stalks were taken for chemical analyses of the juice and the determination of the quality ratio. In this work damaged stalks interfered with securing uniformly satisfactory results.

(4) Owing to the age and condition of the stalks little good seed was available and it was generally agreed to secure desired seed from the ratoon growth. However, top growth seed-pieces were cut from some of the stalks in a few stools of several progenies and placed in germination boxes.

(5) The yield expressed as tons per acre was calculated for each stool by multiplying its weight by the factor .8712. This ton per acre figure simply shows the yield of each stool on a 25 square foot area, or 1/1742.4 part of an acre, calculated to the acre basis. No reduction or other adjustment to plantation conditions was attempted, and these figures were used in order to more graphically represent the comparative stool and progeny yields.

Table 1 shows the summary of the yield data for all progeny planting except that in the outside row on the east side. In this table the number of stools harvested in each progeny is given, followed by the averages for each characteristic recorded. The performance record data for the progenies grown in pukas is given first in a group and those grown in trenches as another group. The performance record averages of two inside rows of puka plantings is next compared with the performance record averages of two inside rows of trenches. Next the average data for all puka and trench planting shown in Table 1 is presented. The average weight per stalk and average weight per foot of stalk for all stalks is shown.

The puka average yield as shown in Table 2 is 163.10 tons per acre with an average quality ratio of 10.32.

The trench average yield as shown in Table 2 is 144.51 tons per acre with an average quality ratio of 9.30.

The average yield of the two inside rows of puka planting as shown in Table 2 was 164.68 tons per acre as compared with the average yield for the trench planting of 101.23 tons per acre.

The average yield for both puka and trench plantings as shown in Table 2 was 156.12 tons per acre with an average quality ratio of 10.05.

The average weight per stalk in both puka and trench plantings as shown in Table 2 was 10.88 pounds and the average weight per foot of stalk was .606 pounds.

In Table 3, the progeny comparative average yields in tons per acre and average quality ratio is shown arranged in the order of yields.

TABLE I.

Summary of Progeny Performance Record Data.

No. of Stools	Progeny	Average No. Healthy Stalks	Average No. Healthy Plants	Average No. Dead Stalks	Borer	Mech.	Tassel	Average Length	Q. R.	T. P. A.	Notes
19	48	16.32	205.77	6.68	8.32	2.53	4.77	16.96	10.11	179.26	Puka
8	S	20.13	232.44	5.50	8.12	4.00	4.25	18.40	9.89	202.49	"
5	V	18.20	215.30	8.00	9.00	1.80	2.66	17.90	10.93	187.66	"
7	156	9.40	107.50	4.70	4.00	1.50	2.50	18.20	11.10	93.65	"
5	153	13.00	149.60	4.60	5.00	1.80	3.20	18.40	11.68	130.33	"
9	94	15.70	174.30	4.70	7.00	2.20	5.00	18.50	10.02	152.85	"
11	155	13.36	162.14	4.36	6.27	1.33	4.33	19.00	13.32	141.25	"
5	154	12.20	165.80	3.20	5.20	1.00	5.00	19.40	9.37	144.46	"
8	142	16.60	221.70	2.00	7.00	2.00	4.75	18.10	9.73	193.13	"
6	63	18.80	236.60	3.60	9.50	1.60	7.00	18.40	.....	205.89	"
83											
Total		153.71	1871.15	47.34	69.41	19.76	43.46	183.26	.....	1630.97	"
Average		15.37	187.12	4.73	6.94	1.98	4.35	18.33	10.32	163.10	"
Trench Planting											
3	94	21.70	199.80	4.70	8.70	8.00	4.00	16.50	.....	174.09	Trench
8	155	12.00	115.81	11.25	7.00	3.42	2.71	17.73	13.60	100.89	"
3	154	11.33	93.17	8.00	9.00	10.70	3.00	19.90	.....	82.91	"
19	142	11.40	120.66	10.95	5.77	2.95	5.54	16.96	9.50	105.14	"
5	63	25.40	289.00	3.33	5.40	4.75	7.40	16.90	8.74	251.78	"
5	156	18.50	174.80	12.60	10.00	4.50	5.25	16.02	14.06	152.29	"
43											
Total		100.33	993.24	50.83	45.87	34.32	27.90	104.01	.....	867.10	"
Average		16.72	165.54	8.47	7.64	5.72	4.65	17.33	9.30	144.51	"
Puka vs. Trench Planting—2 Inside Lines of Each											
20	142, 153, 154, 155	14.9	189.03	3.26	6.35	1.92	4.58	18.38	.....	164.68	Puka
22	142, 154, 155, 156	11.86	116.16	11.05	6.90	4.00	5.19	16.86	.....	101.23	Trench
Average for All Progenies.											
126 stools		15.88	172.71	6.14	7.21	3.38	4.46	17.95	10.05	156.12	

TABLE II.

Puka and Trench Average Yields.

No. Stools	Kind of Planting	Tons per Acre
83	Puka	163.10
43	Trench	144.51
126	Puka and Trench	156.12
20	Two comparative lines of Puka	164.68
22	Two comparative lines of Trench	101.23

Average weight per stalk.................... 10.88 lbs.
Average weight per foot of stalk............. .606 lbs.

TABLE III.

Progeny Comparative Average Yields Arranged in Order of Yields per Acre.

Puka Planting.

Rank	Progeny	No. of Stools	Tons per Acre	Q. R.
1	63	6	205.89	8.91
2	S	8	202.49	9.89
3	142	8	193.13	9.73
4	V	5	187.66	10.93
5	48	19	179.26	10.11
6	94	9	152.85	10.02
7	154	5	144.46	9.37
8	155	11	141.25	13.23
9	153	5	130.33	11.68
10	156	7	93.85	Not taken
	Average yield		163.10	10.32

Trench Planting.

Rank	Progeny	No. of Stools	Tons per Acre	Q. R.
1	63	5	251.78	8.74
2	94	4	174.89	Not taken
3	156	5	152.29	14.06
4	142	19	105.14	9.50
5	155	8	100.89	13.60
6	154	3	82.91	Not taken
	Average yield		144.51	9.30

It will be noted in Table 3 that the higher average quality ratios are usually correlated with the best yielding progenies and the lower quality ratios are correlated with the poorer progenies. This is a fundamentally important consideration. It appears to be a somewhat similar condition to that found in citrus fruit improvement work where high yields within the variety are usually correlated with the best commercial quality.

In Tables 4 to 12 inclusive, the yields of the individual stools of each progeny are presented. The yields of the puka stools have been grouped separately from

those of the trench stools. The total and average figures for each group have been determined for comparative purposes.

It will be noted that of the ten progenies grown in pukas only six were grown in the trenches. Furthermore the number of stools of each progeny in each kind of planting varies, the maximum number being nineteen while the minimum number is three. It is also obvious from a study of the arrangement of the progenies in the plot as shown in Map 1 that there is a larger proportion of outside to inside stools in some progenies than in others. In addition to these difficulties in making accurate progeny yield comparisons the plan of planting did not provide for the systematic repetitions of each progeny in different parts of the plot.

In Table 13, the performance record of the outside row of stools in the east side of the plot is given. This row has not been used in comparing progeny behavior from the fact that the planting was done at a widely different time from that of the remainder of the plot, for the reason that the young plants of the H 109 progenies used for planting were those which had survived drought and neglect in the germination boxes, and to extreme differences of environment and other conditions in the row. For example, in stool 44-8 of P. 63, the stalks were completely overshadowed by the adjoining stools of Uba. Furthermore, at some time several stalks of this stool had been taken out and their weight lost as they could not be found at the time of harvest. The main item of interest in this row is the performance record of the four stools of Uba showing an astonishingly high yield both in number of stalks per stool and total weight of stalks.

In Table 14, the comparative progeny yields computed to tons per acre are shown as percentages above or below the average. This table shows the superior yielding characteristics of Progenies 63, 142, S, V, 48, as compared with Progenies 153, 154, 155. The yield of Progeny 94 is slightly below the average in the pukas and considerably above it in the trenches, while the yield of Progeny 156 is very much below the average in the pukas and slightly above it in the trenches. From careful observation of the characteristics of the individual stools of these two progenies during harvest, the indications were that P. 94 was a somewhat superior progeny while P. 156 was an inferior one.

In Table 15, the performance records of two rows of puka stools are compared with two rows of trench stools. It is believed that this table gives a more accurate measure of comparative puka and trench stool behavior than where all of the puka and all of the trench stools were used for this comparison. It will be noted that the average yield of the puka stools was at the rate of 164.68 tons per acre while that of the trench stools was 101.23 tons per acre. It will also be seen that there was an average of 3.26 dead stalks in the puka stools as compared with an average of 11.05 dead stalks in the trench stools. The number of borer-damaged stalks noted in the pukas averaged 6.35 stalks per stool as compared with 6.90 in the trench stools, a practically even condition in this respect. The average number of mechanically injured or broken stalks in the puka stools was 1.92 while in the trench stools it was 4.00 indicating much greater wind or other damage in the trenches than in the pukas as illustrated in Figs. 1 and 2. The average number of tasseled stalks noted in puka stools was 4.58 while in the trench stools the average number of tasseled stalks was 5.19, practically the same

Fig. 1. Puka stools showing better supported and less damaged stalks as compared with the trench planting.

Fig. 2. One of the rows of trenches running north and south, showing very recumbent and damaged condition of stalks typical of the stools in these rows.

under both conditions. The average length of stalks in the puka stools was 18.38 feet as compared with an average length of 16.86 feet in the trench stools.

In Table 16, is shown the percentage of dead stalks in each progeny, of dead stalks in pukas and trenches, and above or below the average in pukas and in trenches. It will be noted that there was an average of 23.58 per cent dead stalks in the puka stools as compared with an average of 34.67 per cent dead stalks in the trench stools. The average percentage of dead stalks in all puka and trench stools was 27.78 per cent. The stalks in the puka stools showed a more frequent tendency to lala. It is also apparent that there was a smaller percentage of dead stalks in Progenies 63 and 94 than in others.

In Table 17, is shown the percentage of stalks noted with borer damage in puka as compared with trench stools, and the percentage of borer-injured stalks in each progeny as well as the percentage above or below the average in puka and trench plantings. The average per cent of borer-injured stalks in puka stools was 34.25 while that for trench stools was 31.07. There is no apparently consistent relation of borer injury to progenies. The rat-eaten stalks were found in about equal numbers in puka and trench stools.

In Table 18, is shown the number and percentage of second season and first season stalks for all stools of all progenies in both puka and trench plantings. There was an average of 4.63 second season stalks per stool or 29.68 per cent, in the puka planting as compared with an average of 4.39 stalks per stool, or an average of 29.23 per cent, in the trench planting, practically no difference in the characteristic. However, it will be noticed that the superior yielding progenies usually show a higher percentage of second season stalks than the poor yielding progenies.

In Table 19, is shown the performance record of all outside stools for comparison with that of an equal number of inside stools. The inside stools were in three rows running in a diagonal position across the plot. The average yield of the inside stools was at the rate of 137.16 tons per acre while that of the outside stools was at the rate of 214.04 tons per acre, or about 35 per cent increase in yield due to outside position. The appearance of the stalks in the outside puka stools is illustrated in Fig. 3. The average number of stalks per stool inside the plot was 13.26 as compared with 20.84 outside. The average length of stalks in inside stools was 18 feet as compared with 16.41 outside, indicating a stretching up for light on the part of the inside stalks. The average dead stalks per stool inside was 8.20 per stool while outside it was 6.43 showing the effect of competition in the inside stools. The average number of tasseled stalks per stool inside was 3.61 while outside it was 7.28. The number of tasseled stalks outside was about double that of the inside stalks. The borer-injured stalks inside was 5.93 per stool and 9.29 per stool for the outside stools. The average number of broken stalks per stool inside was 3.62 as compared with 2.58 stalks per stool on the outside. The average quality ratio for the stalks inside was 9.82 as compared with 9.85 for the outside stools. These data indicate that the quality ratio was not affected by the inside or outside position of the stools.

In Table 20, is shown the average quality ratio for puka and trench plantings in each progeny, and the average quality ratio of each progeny. These data indicate that the quality ratio was not seriously affected, as a rule, by the position

of the stools in pukas or in trenches. They also indicate that the superior yielding progenies usually had the best quality ratios while the inferior yielding progenies had the poorer quality ratios. These observations are of fundamental

Fig. 3. Stalks from puka stools showing a group of uniformly large stalks.

significance in that they indicate that the quality ratio is not seriously influenced by certain environmental conditions within the H 109 variety and that the quality ratio is a comparatively stable character which is inherent and capable of improvement through bud selection.

Summary.

The average yield of all of the 126 H 109 stools in this plot was at the rate of 156.12 tons per acre. The figure was calculated from the basis of each stool occupying 25 square feet of area and without any reductions for any cause. It is simply a comparative figure for this study and is not intended to be directly applicable to plantation practices. The average quality ratio for all of the H 109 stools in the plot was 10.05. In this plot the average number of healthy stalks per stool was 15.88 and the average weight per stool was 172.71 pounds. The average number of dead stalks per stool was 6.14, the average number of stalks per stool injured by borer was 7.21, the average number of stalks in each stool found to have been broken or injured mechanically was 3.38 and the average number of tasseled stalks in each stool was 4.46. The average length of the stalks of all stools was 17.95 feet. The average weight of stalks was 10.88 pounds per stalk and the average weight per foot of stalk was .606 pounds.

The average yield of the 83 stools in the puka planting was at the rate of 163.10 tons per acre while the average yield of the 43 stools in the trench planting was at the rate of 144.51 tons per acre. The average quality ratio for the puka stools was 10.32. In the puka stools there was an average of 15.37 healthy stalks per stool while in the trenches the average number of healthy stalks was 16.72. The average weight of stalks in the puka stools was 187.12 pounds while in the trenches this figure was 165.54 pounds. The average number of dead stalks in the puka stools was 4.73 while in the trenches it was 8.47. The average borer damage in the pukas was 6.94 stalks per stool while in the trenches it was 7.64 stalks per stool. The average number of broken stalks in puka stools was 1.98 and in the trench stools it was 5.72. The average number of tasseled stalks in the puka stools was 4.35 while in the trenches it was 4.65 stalks. The average length of stalks in puka stools was 18.33 feet while in the trenches it was 17.33 feet. In the selected comparative puka and trench rows the differences in yield were even more marked than where all of the puka and all of the trench stools were considered.

The average number of dead stalks per stool in the pukas was 4.73 while in the trenches it was 8.47. The sides of the pukas seemed to hold up and protect the stalks somewhat so that there was apparently less competition and struggle for existence in the puka stools than was the case with the trench stools.

Borer damage was about the same in the puka planting as in the trench planting. Broken stalks, largely damage due to windstorms, amounted to an average of only 1.98 stalks per stool in the pukas as compared with an average of 5.72 stalks per stool in the trenches.

The heavy yielding stools were almost invariably composed of uniformly large and heavy stalks, as illustrated in Figs. 4 and 5. The lighter yielding stools were usually made up of stalks which varied greatly in size, weight and other characteristics.

While there was but little difference in the average number of tasseled stalks in puka stools as compared with trench stools, the inside stools were found to have an average of 3.61 tassels per stool as compared with an average of 7.28 tassels per stool on the outside of the plot.

Fig. 4. H 109 stool showing uniformly good stalks.

Fig. 5. H 109 stool showing considerable variation in size of stalks.

The outside stools out-yielded the inside stools at the rate of about 35 per cent in tons per acre, which was largely due to larger and heavier stalks.

The quality ratio did not seem to be affected to any extent by the position, being about the same for inside and outside stools and for puka and trench stools.

The quality ratio was apparently inherent with progenies and with yields, the superior and higher yielding stools and progenies, as a rule, having the higher quality ratio.

High yield and high quality ratio are apparently correlated in this experiment.

The Uba stool, as illustrated in Fig. 6, produced a very high yield of cane and a fair quality ratio. Only a few stalks of Uba were found to be injured by borers and there was only a small number of dead stalks in these stools.

Suggestions.

Some suggestions arising from a study of this experiment are briefly summarized in the following paragraphs:

Single-eye three-joint cuttings are practicable and their use is important for scientific bud selection studies.

Spaced plantings, the amount of spacing depending upon the soil, climate and other environmental conditions, are fundamentally important in making individual stool studies and in securing definite individual stool and progeny performance record data.

Heavy fertilization, adequate irrigation and the best of cultural conditions are primarily important for this kind of work.

An equal number of stools in each progeny, repeated two or more times if possible, surrounded by a guard row on all sides of the progeny plot is necessary in order to secure accurate comparative stool and progeny performance record data.

A perfect stand is essential and if necessary extra cuttings should be provided for replanting any missing spaces.

A few markedly inferior progenies should be included in every progeny test for comparative purposes and to measure progress.

Systematic observations from the time the cuttings are planted until the plants are harvested are advisable for a full understanding and a correct interpretation of progeny behavior.

The best age for harvesting the plants for performance record study of the H 109 variety seems to be from 12 to 18 months after planting in the progeny field.

The quality ratio is apparently the most stable and therefore one of great interest in bud selection investigation.

Performance records should include individual stool data giving the number of healthy stalks, their weight, the number of dead stalks, the number of stalks attacked by borers or other pests, or diseased stalks, the number of broken stalks or those otherwise damaged, the number of tasseled stalks, the average length of stalks in each stool, the quality ratio of the healthy and uninjured stalks and the number of second season stalks if the crop is carried a second season.

Fig. 6. Uba stool 44-12 after stripping, 144 stalks weighing 334 pounds.

The importance of this work from an economic standpoint seems to be sufficient to justify it as a part of the work of stool and progeny performance record work for the purpose of building up pedigreed plantation plant material through the selection, isolation and propagation of better strains.

TABLE IV.

Yield of Progeny 63, Puka Planting.

Stool No......	No. of Stalks...	Total Weight...	Total Dead.....	Total Borer.....	Total Mech.....	Total Tassel....	Avg. Length...	Tons per Acre...	Quality Ratio...	Notes........
49–1	23	288.0	4	12	2	16	16.9	250.91	7.72	very uniform
49–2	18	228.0	2	11	5	8	18.8	198.63		
49–3	16	179.5	4	6	3	2	21.0	156.38		
49–4	21	263.5	3	10	1	4	16.8	229.56	10.34	very uniform
49–5	20	262.0	2	7	..	7	19.2	228.25		
49–6	15	197.0	7	11	..	5	18.2	171.63		
Total.....	113	1418.0	22	57	10	42	110.9	1235.36		
Average ..	18.8	236.6	3.6	9.5	1.6	7.0	18.4	205.89		

Yield of Progeny 63, Trench Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
45–1	25	251.0	6	7	2	10	13.0	218.67		
45–2										20 first season shoots taken out 1923, on account of Yellow Stripe.
45–3										
45–4	31	415.0	..	6	..	9	16.1	361.55	8.62	very uniform
45–5	25	260.0	2	5	4	4	17.6	226.51		
45–6	20	214.0	..	5	9	6	20.2	186.44		
45–7	26	305.0	2	4	4	8	17.8	265.72	8.77	very uniform
Total.....	127	1445.0	10	27	19	37	84.7	1258.89		
Average ..	25.4	289.0	3.33	5.4	4.75	7.4	16.9	251.78		

TABLE V.

Yield of Progeny S, Puka Planting.

Stool No......	No. of Stalks...	Total Weight...	Total Dead.....	Total Borer.....	Total Mech.....	Total Tassel....	Avg. Length...	Tons per Acre...	Quality Ratio...	Notes........
55–4	17	184.0	7	8	3	1	17.8	160.30		
55–5	10	109.5	7	5	3	..	17.0	95.40		
54–4	16	163.5	6	7	2	3	17.2	142.44		
54–5	23	222.0	3	8	6	6	20.0	193.41		
54–6	15	225.0	5	6	6	6	24.0	196.02		
54–7	23	274.0	5	2	..	2	18.5	238.71	10.77	very uniform
54–8	20	267.5	6	10	..	5	16.5	233.04	8.99	very uniform
54–9	36	414.0	5	19	..	11	17.5	360.67	9.89	very uniform
Total.....	161	1859.5	44	65	20	34	147.5	1619.99		
Average ..	20.13	232.44	5.5	8.12	4.0	4.25	18.4	202.49		

TABLE VI.

Yield of Progeny V, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
55–6	13	127.0	9	9	3	1	17.4	110.64		
55–7	20	232.5	13	14	2	2	17.5	202.99		
54–1	22	291.0	6	8	2	4	18.5	253.52	8.53	
54–2	17	236.0	7	7	1	..	19.7	205.60	13.88	
54–3	19	190.0	5	7	1	1	16.4	165.53		
Total.....	91	1076.5	40	45	9	8	89.5	938.28		
Average —	18.2	215.3	8.0	9.0	1.8	2.66	17.9	187.66		

TABLE VII.

Yield of Progeny No. 142, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
50–1	19	298.0	1	5	2	8	17.8	259.62	8.20	
50–2	15	200.0	3	5	2	4	17.8	174.24		
50–3	13	182.5	2	2	1	3	19.6	158.99		
50–4	14	179.5	1	9	1	5	17.0	156.38		
50–5	16	190.0	..	10	2	4	19.7	165.53		
50–6	24	265.0	2	11	4	5	17.4	230.86		very uniform
50–7	17	236.0	2	4	2	3	16.7	205.60	9.03	uniform
50–8	15	222.5	2	10	..	6	18.6	193.84	10.47	uniform
Total.....	133	1773.5	14	56	14	38	144.6	1545.06		
Average ..	16.6	221.7	2	7	2	4.75	18.1	193.13		

Yield of Progeny No. 142, Trench Planting.

47–1	19	219.5	10	10	4	7	16.6	191.23
47–2	4	22.0	15	1	3	..	14.2	19.17
47–3	10	105.5	10	3	3	1	18.4	91.91
47–4	4	16.0	16	..	4	..	10.0	13.94
47–5	5	63.0	13	2	4	2	18.0	54.89
47–6	4	30.0	16	4	3	..	19.0	26.14
46–1	18	257.5	5	6	1	9	14.4	224.33
46–2	12	142.0	14	3	2	4	18.0	123.71
46–3	11	126.5	13	1	2	1	16.4	110.21
46–4	11	136.5	15	3	3	8	21.0	118.92

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
46–5	5	61.0	16	1	2	3	16.4	53.14		
46–6	5	58.5	12	..	2	2	21.6	50.97		
46–7	13	72.0	14	12	7	..	14.3	62.73		
46–8	8	63.5	15	2	3	..	14.5	55.32		
46–9	11	94.5	6	9	..	4	19.6	82.33		
46–10	11	153.5	4	11	3	6	20.9	133.73	11.93	
46–11	34	265.5	8	15	3	11	10.6	231.96	8.65	
45–11	16	233.0	2	11	1	14	22.0	202.77	9.29	
45–12	15	172.5	4	4	3	..	16.4	150.28	8.94	
Total.....	218	2292.5	208	98	53	72	322.3	1997.68		
Average ..	11.5	120.66	10.95	5.77	2.95	5.54	16.96	105.14		

TABLE VIII.

Yield of Progeny No. 48, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
57–1	21	315.0	5	11	1	10	18.4	274.42	8.99	very uniform
57–2	17	237.5	4	8	2	1	17.5	206.91		
57–3	12	166.5	12	6	2	1	19.5	145.05		
57–4	17	212.0	4	8	3	6	17.2	184.69		
57–5	15	202.0	7	4	2	5	17.8	175.98		
57–6	13	192.5	10	6	2	8	16.8	167.71		
57–7	13	174.5	11	5	3	3	16.9	152.02		
56–1	23	310.5	3	14	6	13	15.8	270.51	10.93	
56–2	11	135.0	1	9	3	1	15.4	117.61		
56–3	14	178.0	6	8	2	6	16.0	155.07		
56–4	10	120.0	8	3	2	4	16.8	104.54		
56–5	7	89.5	10	6	2	1	17.7	77.97		
56–6	26	283.5	5	16	4	5	17.3	246.99	10.25	very uniform stalks
56–7	11	155.0	7	7	2	5	16.2	135.04		
56–8	19	223.0	10	11	3	4	16.3	194.28		
55–1	23	293.5	5	10	2	7	16.1	255.70	9.77	
55–2										missing
55–3	13	147.0	6	7	2	1	18.2	128.07		
55–8	19	212.0	1	7	..	..	17.1	184.69	10.86	
55–9	26	262.5	12	12	..	..	15.4	228.69		
Total.....	310	3909.5	127	158	43	81	322.4	3405.94		
Average ..	16.32	205.77	6.68	8.32	2.53	4.77	16.96	179.26		

TABLE IX.

Yield of Progeny No. 94, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
53–7	2	17.5	6	1	..	..	24.0	15.25		
53–8	3	33.0	3	2	1	..	18.0	28.75		
53–9	5	72.5	3	1	..	..	22.0	63.16		
53–10	26	277.5	..	7	1	2	15.4	241.75	10.19	
49–7	15	163.0	3	10	5	2	20.3	142.01		
49–8	14	169.5	6	10	3	1	17.0	147.67		
49–9	21	249.0	3	6	..	4	16.7	216.93	9.33	uniform
49–10	22	278.0	6	13	1	5	15.6	242.19	11.54	
49–11	33	319.0	11	14	..	16	15.7	277.91	9.08	uniform
Total.....	141	1579.0	41	64	11	30	164.7	1375.62		
Average ..	15.7	174.3	4.7	7.0	2.2	5.0	18.5	152.85		

Yield of Progeny No. 94, Trench Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
45–8	35	276.5	3	4	11	4	13.0	240.89		
45–9	19	177.0	6	11	..	4	16.5	154.20		
45–10	11	146.0	5	11	5	..	20.0	127.20		
Total.....	65	599.5	14	26	16	8	49.5	522.29		
Average ..	21.7	199.8	4.7	8.7	8.0	4.0	16.5	174.09		

TABLE X.

Yield of Progeny No. 154, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
51–4	12	161.5	3	9	1	5	21.7	140.70		
51–5	10	114.5	5	3	1	2	17.8	99.75		
51–6	17	194.0	3	9	..	5	18.0	169.01		
51–7	9	148.0	3	3	..	6	20.0	128.94		
51–8	13	211.0	2	2	..	7	19.3	183.82	9.37	fairly uniform
Total.....	61	829.0	16	26	2	25	96.8	722.32		
Average ..	12.2	165.8	3.2	5.2	1.0	5.0	19.4	144.46		

Yield of Progeny No. 154, Trench Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
47–7	9	99.5	10	3	9	1	20.0	86.68		
47–8	10	54.5	11	10	10	..	20.0	47.48		
47–9	15	131.5	3	14	13	5	19.6	114.56		
Total.....	34	285.5	24	27	32	6	59.6	248.72		
Average ..	11.33	93.17	8.0	9.0	10.7	3.0	19.9	82.91		

TABLE XI.

Yield of Progeny No. 155, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Tassel	Total Mech.	Avg. Length	Tons per Acre	Quality Ratio	Notes
52–1	19	300.0	1	5	1	9	18.4	261.36		
52–2	6	58.5	10	3	..	..	21.0	50.97		
52–3	13	163.5	6	8	2	3	20.0	142.44		
52–4	6	65.0	4	2	1	..	18.8	56.63		
52–5	11	144.0	4	5	2	2	19.1	125.45		
52–6	12	124.0	4	4	..	3	21.0	108.03		
52–7	12	148.0	3	5	1	6	18.0	128.94		
52–8	14	172.5	5	7	1	4	21.1	150.28		
52–9	15	178.0	1	10	..	4	17.3	155.07	11.80	
51–9	17	191.0	6	10	..	1	17.8	166.40		
51–10	22	239.0	4	10	..	7	16.5	208.22	14.29	
Total.....	147	1783.5	48	69	8	39	209.0	1553.79		
Average ..	13.36	162.14	4.36	6.27	1.33	4.33	19.0	141.25		

Yield of Progeny No. 155, Trench Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Tassel	Total Mech.	Avg. Length	Tons per Acre	Quality Ratio	Notes
48–1	17	206.5	7	12	2	5	17.6	179.90		
48–2	11	73.0	12	6	3	1	16.5	63.60		
48–3	14	151.5	8	7	..	3	19.7	131.99		
48–4	13	146.0	12	7	2	5	17.0	127.20		
48–5	3	26.5	17	1	1	..	18.7	23.09		
48–6	14	95.0	13	7	7	1	19.6	82.76		
48–7	13	120.0	11	7	8	1	18.0	104.54		
47–10	11	108.0	10	9	1	3	14.8	94.08	13.60	
Total.....	96	926.5	90	56	24	19	141.9	807.17		
Average ..	12.0	115.81	11.25	7.00	3.42	2.71	17.73	100.89		

TABLE XII.

Yield of Progeny No. 156, Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
53–1	10	112.5	9	6	2	1	18.2	98.01		
53–2	4	40.5	7	1	1	..	18.0	35.28		
53–3	9	109.0	2	4	3	3	16.5	94.96		
53–4	7	74.0	5	4	3	1	21.0	64.47		
53–5	6	90.5	3	..	..	3	18.9	78.84		
53–6	6	78.0	3	2	..	1	19.0	67.95		
52–10	24	248.0	4	11	2	9	15.9	216.06	11.10	
Total.....	66	752.5	33	28	11	18	127.5	655.57		
Average ..	9.4	107.5	4.7	4.0	1.5	2.5	18.2	93.65		

YIELD OF PROGENY NO. 156, TRENCH PLANTING.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
48–8	10	125.5	10	7	5	1	14.0	109.34		
48–9	12	83.5	10	9	11	..	22.5	72.75		
48–10	20	210.0	6	12	1	2	16.5	182.95	14.63	
48–11	21	180.0	10	13	..	2	14.5	156.82	13.40	
47–11	31	275.0	7	19	1	16	12.6	239.58		tassel
Total.....	94	874.0	63	50	18	21	80.1	761.44		
Average ..	18.50	174.8	12.6	10.0	4.5	5.25	16.02	152.29		

TABLE XIII.

YIELD OF PROGENY NO. 153, PUKA PLANTING.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Length	Tons per Acre	Quality Ratio	Notes
51–1	17	223.5	4	3	3	5	18.1	194.71		
51–2	11	107.5	6	4	4	3	19.0	93.65		
51–3	4	39.5	7	1	1	..	20.0	34.41		
50–9	17	189.5	2	10	..	3	18.4	165.09	11.99	
50–10	16	188.0	4	7	1	5	16.3	163.79	11.36	
Total.....	65	748.0	23	25	9	16	91.8	651.65		
Average ..	13.0	149.6	4.6	5.0	1.8	3.2	18.4	130.33		

YIELD OF OUTSIDE ROW, EAST SIDE, PUKA PLANTING, LYMAN SEEDLING.

44–1	8	79.0	4	8	1	2	10.9	68.82	7.05

Progeny No. 142.

44–2	16	149.0	..	11	..	4	14.9	129.81	
44–3	19	159.5	..	10	..	7	13.8	138.96	
44–4	24	189.5	2	11	2	8	12.2	165.09	
44–5	19	177.5	2	4	2	5	13.3	154.64	
Total.....	68	675.5	4	36	4	24	54.2	588.50	
Average ..	17.0	168.9	2.0	9.0	2.0	6.0	13.6	147.13	

Progeny No. 155

44–6	21	193.5	..	5	2	8	15.3	168.58	9.52
44–7	13	123.5	..	5	1	3	13.9	107.59	
Total.....	34	317.0	..	10	3	11	29.2	276.17	
Average ..	17.0	158.5	..	5.0	1.5	5.5	14.6	138.09	

Progeny No. 63.

44–8	8	72.0	..	5	..	3	16.7	62.73	

Uba.

Stool No.	No. of Stalks...	Total Weight...	Total Dead.....	Total Borer.....	Total Tassel....	Total Mech.....	Avg. Length....	Tons per Acre..	Quality Ratio...	Notes.........
44–9	101	299.5	12	6	6	1	10.0	260.92	10.53	
44–10	95	233.5	6	3	9	..	9.0	203.43	10.11	
44–11	92	215.0	8	2	..	..	10.0	187.31	11.56	
45–12	144	334.0	7	..	..	..	11.0	290.98	9.85	
Total.....	432	1082.0	33	11	15	1	40.0	942.64		
Average ..	108	270.5	8.3	3.7	7.5	1.0	10.0	235.66		

TABLE XIV.

Comparative Progeny Yields per Acre Expressed in Percentages Above or Below the Average.

Puka Planting.

Average yield 163.10 T. P. A. = 100%.

No. of Stools	Progeny	Percentage Above or Below 100	Plus	Minus
19	48	109.91	9.91	.....
9	S	124.15	24.15	.....
5	V	115.06	15.06	.....
7	156	57.42	.....	42.48
5	153	79.91	.....	20.09
9	94	93.72	.....	6.28
11	155	86.60	.....	13.40
5	154	88.57	.....	11.43
8	142	118.41	18.41	.....
6	63	126.24	26.24	.....

Trench Planting.

Average yield 144.51 T. P. A. = 100%.

4	94	120.47	20.47	.....
8	155	68.81	.....	31.12
3	154	57.37	.....	42.63
19	142	72.76	.....	27.24
5	63	174.23	74.23	.....
5	156	105.38	5.38	.....

TABLE XV.

Comparative Yields of Puka and Trench Plantings Two Rows of Each.

Puka Planting.

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Weight	Tons per Acre	Progeny No.
51–1	17	223.5	4	3	3	5	18.1	194.71	153
51–2	11	107.5	6	4	4	3	19.0	93.65	153
51–3	4	39.5	7	1	1	..	20.0	34.41	153

Stool No.	No. of Stalks	Total Weight	Total Dead	Total Borer	Total Mech.	Total Tassel	Avg. Weight	Tons per Acre	Progeny No.
51–4	12	161.5	3	9	1	5	21.7	140.70	154
51–5	10	114.5	5	3	1	2	17.8	99.75	154
51–6	17	194.0	3	9	..	5	18.0	169.01	154
51–7	9	148.0	3	3	..	6	20.0	128.94	154
51–8	13	211.0	2	2	..	7	19.3	183.82	154
51–9	17	191.0	6	10	..	1	17.8	166.40	155
51–10	22	239.0	4	10	..	7	16.5	208.22	155
50–1	19	298.0	1	5	2	8	17.8	259.62	142
50–2	15	200.0	3	5	2	4	17.8	174.24	142
50–3	13	182.5	2	2	1	3	19.6	158.99	142
50–4	14	179.5	1	9	1	5	17.0	156.38	142
50–5	16	190.0	..	10	2	4	19.7	165.53	142
50–6	24	265.0	2	11	4	5	17.4	230.86	142
50–7	17	236.0	2	4	2	3	16.7	205.60	142
50–8	15	222.5	2	10	..	6	18.6	193.84	142
50–9	17	189.5	2	10	..	3	18.4	165.09	153
50–10	16	188.0	4	7	1	5	16.3	163.79	153
Total	298	3780.5	62	127	25	87	367.5	3293.55	
Average ..	14.9	189.03	3.26	6.35	1.92	4.58	18.38	164.68	

Trench Planting.

47–1	19	219.5	10	10	4	7	16.6	191.23	142
47–2	4	22.0	15	1	3	..	14.2	19.17	142
47–3	10	105.5	10	3	3	1	18.4	91.91	142
47–4	4	16.0	16	..	4	..	10.0	13.94	142
47–5	5	63.0	13	2	4	2	18.0	54.89	142
47–6	4	30.0	16	4	3	..	19.0	26.14	142
47–7	9	99.5	10	3	9	1	20.0	86.68	154
47–8	10	54.5	11	10	10	..	20.0	47.48	154
47–9	15	131.5	3	14	13	5	19.6	114.56	154
47–10	11	108.0	10	9	1	3	14.8	94.09	155
47–11	31	275.0	7	19	1	16	12.6	239.58	156
46–1	18	257.5	5	6	1	9	14.4	224.33	142
46–2	12	142.0	14	3	2	4	18.0	123.71	
46–3	11	126.5	13	1	2	1	16.4	110.21	
46–4	11	136.5	15	3	3	8	21.0	118.92	
46–5	5	61.0	16	1	2	3	16.4	53.14	
46–6	5	58.5	12	..	2	2	21.6	50.97	
46–7	13	72.0	14	12	7	..	14.3	62.73	
46–8	8	63.5	15	2	3	..	14.5	55.32	
46–9	11	94.5	6	9	..	4	19.6	82.33	
46–10	11	153.5	4	11	3	6	20.9	133.73	
46–11	34	265.5	8	15	3	11	10.6	231.96	
Total	261	2555.50	243	138	84	83	370.9	2227.02	
Average ..	11.86	116.16	11.05	6.90	4.00	5.19	16.86	101.23	

TABLE XVI.

Comparative Dead Stalk Data in Different Progenies.

Puka Planting.

No. of Stools	Progeny No.	No. Stalks Living	No. Stalks Dead	Total	Per Cent Dead	Total Plus	Average Minus
19	48	16.32	6.68	23.00	29.04	5.46	.....
8	S	20.13	5.50	25.63	21.46	....	2.12
5	V	18.20	8.00	26.20	30.53	7.05	.....
7	156	9.40	4.70	14.10	33.33	9.75	.....
5	153	13.00	4.60	17.60	26.15	2.57	.....
9	94	15.70	4.70	20.40	23.04	....	.54
11	155	13.36	4.36	17.72	24.60	1.02	.....
5	154	12.20	3.20	15.40	20.78	....	2.80
8	142	16.60	2.00	18.60	10.75	....	12.83
6	63	18.80	3.60	22.40	16.07	....	7.51
	Total				235.75		

Trench Planting.

No. of Stools	Progeny No.	No. Stalks Living	No. Stalks Dead	Total	Per Cent Dead	Total Plus	Average Minus
4	155	12.00	11.25	23.25	48.39	13.61	.....
8	154	11.33	8.00	19.33	41.39	6.61	.....
3	142	11.40	10.95	22.35	48.99	14.21	.....
19	63	25.40	3.33	28.73	11.59	.....	23.19
5	156	18.50	12.60	31.10	40.51	5.73	.....
5	94	21.70	4.70	26.40	17.80	.....	16.98
	Total				208.67		
	Average				34.78		
	Average for Puka and Trench Stools				27.78		

TABLE XVII.

Comparative Borer Damage in Progenies.

Puka Plantings.

No. of Stools	Progeny	Total Stalks	Borer Stalks	Per Cent Borer	Progenies Most Damage Plus	Progenies Least Damage Minus
19	48	23.00	8.32	36.17	1.92	....
8	S	25.63	8.12	31.68	....	2.57
5	V	26.20	9.00	34.35	.10	....
7	156	14.10	4.00	28.37	....	5.88
5	153	17.60	5.00	28.41	....	5.84
9	94	20.40	7.00	34.31	.06	....
11	155	17.72	6.27	35.38	1.13	....
5	154	15.40	5.20	33.77	....	.48
8	142	18.60	7.00	37.63	3.38	....
6	63	22.40	9.50	42.41	8.16	....
	Total			342.48		
	Average Puka			34.25		

Trench Plantings.

No. of Stools	Progeny	Total Stalks	Borer Stalks	Per Cent Borer	Progenies Most Damage Plus	Progenies Least Damage Minus
4	94	26.40	8.70	32.96	1.91	....
8	155	23.25	7.00	30.11	....	.94
3	154	19.33	9.00	46.56	15.51	....
19	142	22.35	5.77	25.82	....	5.23
5	63	28.73	5.40	18.80	....	12.25
5	156	31.10	10.00	32.16	1.11	....

Total 186.41
Average Trench 31.07
Average for all Puka and Trench Stools... 33.06

TABLE XVIII.

Comparative Second and First Season Stalk Development in Progenies.

Puka Planting.

Progeny No.	Total No. of Stalks	No. of 2nd Season Stalks	Per Cent 2nd Season Stalks	No. of 1st Season Stalks	Per Cent 1st Season Stalks	Kind of Planting
94	15.67	7.11	45.37	8.56	54.63	Puka
63	18.85	4.33	22.97	14.50	77.03	"
S	20.00	6.87	34.35	13.13	65.65	"
V	18.50	5.00	27.03	13.50	72.97	"
142	16.63	4.75	28.56	11.88	71.44	"
48	16.32	7.32	44.85	9.00	55.15	"
154	12.20	1.80	14.75	10.40	85.25	"
153	13.00	3.00	23.08	10.00	76.92	"
155	13.36	2.80	20.96	10.56	79.04	"
156	9.43	3.29	34.89	6.14	65.11	"
Total	153.96	46.27	296.81	107.67	703.19	"
Average..	15.40	4.63	29.68	10.77	70.32	"

Trench Planting.

Progeny No.	Total No. of Stalks	No. of 2nd Season Stalks	Per Cent 2nd Season Stalks	No. of 1st Season Stalks	Per Cent 1st Season Stalks	Kind of Planting
94	18.83	3.33	18.17	15.00	81.83	Trench
63	25.40	7.40	29.13	18.00	70.87	"
142	11.50	2.87	24.96	8.63	75.04	"
154	11.33	.33	29.13	11.00	70.87	"
155	12.00	2.62	21.83	9.38	78.17	"
156	18.80	9.80	52.13	9.00	47.67	"
Total	97.86	26.35	175.35	71.01	424.45	"
Average..	16.31	4.39	29.23	11.84	70.74	"

TABLE XIX.

Comparative Behavior of Inside and Outside Stools.

Inside Stools.

Progeny	Stool No.	T. P. A.	Weight in Lbs.	No. Stalks	Length Stalk	Dead	Tassel	Borer	Mech.	Q.R.
142	46–2	123.71	142.00	12.00	18.00	14.00	4.00	3.00	2.00	....
155	48–4	127.20	146.00	13.00	17.00	12.00	5.00	7.00	2.00	....
142	47–3	91.91	105.50	10.00	18.40	10.00	1.00	3.00	3.00	....
63	49–5	228.25	262.00	20.00	19.20	2.00	7.00	7.00	....	....
142	50–6	230.86	265.00	24.00	17.40	2.00	5.00	11.00	4.00	....
154	51–7	128.94	148.00	9.00	20.00	3.00	6.00	3.00	....	....
155	52–8	150.28	172.50	14.00	21.10	5.00	4.00	7.00	1.00	....
142	46–3	110.21	126.50	11.00	16.40	13.00	1.00	1.00	2.00	....
142	47–4	13.94	16.00	4.00	10.00	16.00	....	....	4.00	....
155	48–5	23.09	26.50	3.00	18.70	17.00	....	1.00	1.00	....
63	49–6	171.63	197.00	15.00	18.20	7.00	5.00	12.00	....	....
142	50–7	205.60	236.00	17.00	16.70	2.00	3.00	4.00	2.00	9.03
154	51–8	183.82	211.00	13.00	19.30	2.00	7.00	2.00	....	9.37
155	52–9	155.07	178.00	15.00	17.30	1.00	4.00	10.00	....	11.80
142	46–4	118.92	136.50	11.00	21.00	15.00	8.00	3.00	3.00	....
142	47–5	54.89	63.00	5.00	18.00	13.00	2.00	2.00	4.00	....
155	48–6	82.76	95.00	14.00	19.60	13.00	1.00	7.00	7.00	....
94	49–7	142.01	163.00	15.00	20.30	3.00	2.00	10.00	5.00	....
142	50–8	193.84	222.50	15.00	18.60	2.00	6.00	10.00	....	10.47
155	51–9	166.40	191.00	17.00	17.80	6.00	1.00	10.00	....	....
63	45–4	361.55	415.00	31.00	16.10	....	9.00	6.00	....	8.62
142	46–5	53.14	61.00	5.00	16.40	16.00	3.00	1.00	2.00	....
142	47–6	26.14	30.00	4.00	19.00	16.00	....	4.00	3.00	....
155	48–7	104.54	120.00	13.00	18.00	11.00	1.00	7.00	8.00	....
94	49–8	147.67	169.50	14.00	17.00	6.00	1.00	10.00	3.00	....
153	50–9	165.09	189.50	17.00	18.40	2.00	3.00	10.00	....	11.99
63	45–5	226.51	260.00	25.00	17.60	2.00	4.00	5.00	4.00	....
142	46–6	50.97	58.50	5.00	21.60	12.00	2.00	....	2.00	....
154	47–7	86.68	99.50	9.00	20.00	10.00	1.00	3.00	9.00	....
156	48–8	109.34	125.50	10.00	14.00	10.00	1.00	7.00	5.00	....
94	49–9	216.93	249.00	21.00	16.90	3.00	4.00	6.00	....	9.33
Total		4251.89	4775.00	411.00	558.00	246.00	101.00	172.00	76.00	
Average		137.16	154.03	13.26	18.00	8.20	3.61	5.93	3.62	9.82

Outside Stools.

Progeny	Stool No.	T. P. A.	Weight in Lbs.	No. Stalks	Length Stalk	Dead	Tassel	Borer	Mech.	Q.R.
63	45–1	218.67	251.00	25.00	13.00	6.00	10.00	7.00	2.00	....
142	46–1	224.33	257.50	18.00	14.40	5.00	9.00	6.00	1.00	....
142	47–1	191.23	219.50	19.00	16.60	10.00	7.00	10.00	4.00	....
155	48–1	179.90	206.50	17.00	17.60	7.00	5.00	12.00	2.00	....
63	49–1	250.91	288.00	23.00	16.90	4.00	16.00	12.00	2.00	7.72
142	50–1	259.62	298.00	19.00	17.80	1.00	8.00	5.00	8.00	8.20
153	51–1	194.71	223.50	17.00	18.10	4.00	5.00	3.00	3.00	....
155	52–1	261.36	300.00	19.00	18.40	1.00	9.00	5.00	1.00	....
156	53–1	98.01	112.50	10.00	18.20	9.00	1.00	6.00	2.00	....
V	54–1	253.52	291.00	22.00	18.50	6.00	4.00	8.00	4.00	8.53
48	55–1	255.70	293.50	23.00	16.10	5.00	7.00	10.00	2.00	9.11
48	56–1	270.51	310.50	23.00	15.80	3.00	13.00	14.00	6.00	10.93
48	57–1	274.42	315.00	21.00	18.40	5.00	10.00	11.00	1.00	8.91
48	57–2	206.91	237.50	17.00	17.50	4.00	1.00	8.00	2.00	....
48	57–3	145.05	166.50	12.00	19.50	12.00	1.00	6.00	2.00	....
48	57–4	184.69	212.00	17.00	17.20	4.00	6.00	8.00	3.00	....
48	57–5	175.98	202.00	15.00	17.80	7.00	5.00	4.00	2.00	....
48	57–6	167.71	192.50	13.00	16.80	10.00	8.00	6.00	2.00	....
48	57–7	152.02	174.60	13.00	16.90	11.00	3.00	5.00	3.00	....
48	56–8	194.28	223.00	19.00	16.30	10.00	4.00	11.00	3.00	....
48	55–9	228.69	262.50	26.00	15.40	12.00	....	12.00	....	....
S	54–9	360.67	414.00	36.00	17.50	5.00	11.00	19.00	....	9.89
94	53–10	241.75	277.50	26.00	15.40	....	2.00	7.00	2.00	10.19
156	52–10	216.06	248.00	24.00	15.90	4.00	9.00	11.00	2.00	11.10
155	51–10	208.22	239.00	22.00	16.50	4.00	7.00	10.00	....	14.29
153	50–10	163.79	188.00	16.00	16.30	4.00	5.00	7.00	1.00	11.36
94	49–11	277.91	319.00	33.00	15.70	11.00	16.00	14.00	....	9.08
156	48–11	156.82	180.00	21.00	14.50	10.00	2.00	13.00	....	13.40
156	47–11	239.58	275.00	31.00	12.60	7.00	16.00	19.00	1.00	....
142	46–11	231.96	265.50	34.00	10.60	8.00	11.00	15.00	3.00	8.65
142	45–12	150.28	172.50	15.00	16.40	4.00	....	4.00	3.00	8.94
Total		6635.21	7615.10	646.00	508.60	193.00	211.00	288.00	67.00	
Average		214.04	245.65	20.84	16.41	6.43	7.28	9.29	2.58	9.85

TABLE XX.

Comparative Progeny Average Quality Ratios.

	Progeny	Stool	Weight	Q. R.	Wt. × Q. R.	Ave. Q. R.	
Trench ...	63	45–4	415.00	8.62	3577.30		
" ...	63	45–7	305.00	8.77	2674.85		
			715.00	÷	6252.15 =	8.74	
Puka	63	49–1	288.00	7.72	2223.36		
"	63	49–4	263.50	10.34	2724.59		= 8.84 Avg. Q. R. Prog. 63
			551.50	÷	4947.95 =	8.91	
Puka	S	54–7	274.00	10.77	2950.98		
"	S	54–8	267.50	8.99	2404.83		
"	S	54–9	414.00	9.89	4094.46		
			955.50	÷	9450.27 =	9.89	
Puka	V	54–1	291.00	8.53	2482.23		
"	V	54–2	236.00	13.88	3275.68		
			527.00	÷	5757.91 =	10.93	
Trench ...	142	46–10	153.50	11.93	1831.26		
" ...	142	46–11	265.50	8.65	2296.58		
" ...	142	45–11	233.00	9.29	2164.57		
" ...	142	45–12	172.50	8.94	1542.15		
			824.50	÷	7834.56 =	9.50	
Puka	142	50–7	236.00	9.03	2131.08		
"	142	50–8	222.50	10.47	2329.58		= 9.58 Avg. Q. R. Prog. 142
			458.50	÷	4460.66 =	9.73	
Trench ...	48	55–8	212.00	10.86	2302.32 =	10.86	
Puka	48	57–1	315.00	8.99	2831.85		
"	48	56–1	310.50	10.93	3393.77		
"	48	56–6	283.50	10.25	2905.87		= 10.20 Avg. Q. R. Prog. 48
"	48	55–1	293.50	9.77	2867.50		
			1414.50	÷	14301.31 =	10.11	
Puka	94	53–10	277.50	10.19	2827.73		
"	94	49–9	249.00	9.33	2323.17		
"	94	49–10	278.00	11.54	3208.12		
"	94	49–11	319.00	9.08	2896.52		
			1123.50	÷	11255.54 =	10.02	
Puka	154	51–8	211.00	9.37	1977.07 =	9.37	
Trench ...	155	47–10	108.00	13.60	1468.80 =	13.60	
Puka	155	52–9	178.00	11.80	2100.40		
"	155	51–10	239.00	14.29	3415.31		= 13.30 Avg. Q. R. Prog. 155
			417.00	÷	5515.71 =	13.23	

	Progeny	Stool	Weight	Q. R.	Wt. × Q. R.	Ave. Q. R.	
Trench ...	156	48–10	210.00	14.63	3072.30		
" ...	156	48–11	180.00	13.40	2412.00		
			390.00	÷	5484.30 =	14.06	= 12.91 Avg. Q. R.
Puka	156	52–10	248.00	11.10	2752.80 =	11.10	Prog. 156
Puka	153	50–9	189.50	11.99	2272.11		
"	153	50–10	188.00	11.36	2135.68		
			377.50	÷	4407.79 =	11.68	

Grand Average Q. R.

Trench ...	2249.50	20930.13 =	9.30
Puka	6284.00	64827.01 =	10.32
All	8533.50	85757.14 =	10.05

The above described test was originally suggested by published information from the Cuban Experiment Station wherein enormous yields were reported from widely spaced sugar cane plants. The plants were grown from single eyes which remained upon three-joint cuttings after destroying the other buds. The cuttings were started in small flats or boxes and afterwards planted in holes about 20 inches deep. These holes were gradually filled with stable manure and adequate irrigation supplied, so that the plants at no time lacked water.

In our work, the method reported by the Cuban Station was followed and in addition 100 pounds of nitrogen per month were added for sixteen months, making 1,600 pounds of nitrogen in all. This extremely high fertilization was checked by pot experiments in which double this application showed no visible injury to the cane. In the summer months as much as 8 inches of water a week was applied.

The experiment was one in forced cropping and since selected progenies were used, the opportunity of studying the behavior of the different progenies was followed by A. D. Shamel, who harvested the cane and took weights and measurements. Apart from the bud selection data, this little plot of cane offers some rather interesting information:

1. Notwithstanding the wide spacing, 5 feet apart each way, the factor which finally checked yields more than anything else seemed to be overcrowding.

2. It was very apparent from the condition of this cane at the time of harvest that had it been harvested a few months earlier the yield would have been greater, as the growth which had taken place in the last few months was more than counterbalanced by dead cane. This has strengthened our belief that the two-year cropping period is not an efficient use of time, and that there is much to be gained by studying the possibilities of the shorter periods which would give two crops in three years or thereabouts.

Preservation of Railroad Ties*

The American Wood Preservers' Association consists of representatives of the leading railways in the United States, and representatives of lumbering firms and creosoting plants. Railways which are represented are such as the Atcheson

* Review of the Report of the Committee on Treatment of Railway Ties of the American Wood-Preservers' Association, 1923.

Topeka and Santa Fe, Southern Pacific, New York Central, Pennsylvania, Baltimore and Ohio. The representatives are usually engineers or purchasing agents.

These railways have found that a large part of the maintenance costs of railways consists in tie replacements and the labor involved in such replacements. Working to reduce the costs of these replacements it has been found in years gone by that treatment of the ties with preservatives results in greatly increased length of service; in many cases the length of service of treated ties has been 50 and sometimes 100 per cent greater than untreated ties of the same character. There has resulted from this a somewhat specialized branch of engineering dealing entirely with the preservation of railway ties.

The success of these tie treatments has led to the use of wood preservatives in many other lines of construction. Bridge timbers, marine piles, farm structures, flumes and in fact all sorts of wooden construction exposed to conditions favorable to deterioration are now profitably treated with wood preservatives.

This development has occurred in the United States where temperature and rainfall conditions are temperate; in the tropics, as in this country, wood deterioration is much more rapid due to higher temperatures and more humidity. It would be expected, therefore, that treatment with wood preservatives for railway ties, plantation buildings, fence posts, flumes and flume supports would result in even greater savings than have been possible on the mainland, especially with the high prices for lumber here.

The following are the specifications for the preservative treatment of ties by pressure processes drawn up by the Committee on Treatment of Ties of the American Wood-Preservers' Association and reported at its 1924 meeting:

SPECIFICATION FOR THE PRESERVATIVE TREATMENT OF TIES BY PRESSURE PROCESSES.

General Requirements.

1. The following general requirements (2-8) apply to each of the treatment processes.

2. *Conditioning.* Ties shall be conditioned for treatment in accordance with American Wood-Preservers' Association "Standards for the Purchase and Preservation of Treatable Timber." (See A. W. P. A. Manual of Recommended Practice.)

3. *Seasoning.* (a) Ties shall be seasoned, by air or steam as agreed upon, until in the judgment of the purchaser's representative any moisture in the wood will not prevent the injection and proper distribution of the specified amount of preservative.

(b) When, in the judgment of the purchaser's representative, steam-seasoning is necessary for adequate treatment, cross-ties may be steamed in the cylinder at not more than 30 lbs. pressure per square inch for not more than 10 hours at not more than 275° F., which pressure and temperature maxima shall not be reached in less than two hours. The cylinder shall be provided with vents to relieve it of air and insure proper circulation of steam. After steaming is completed a vacuum shall be maintained at a temperature as high as practicable until the wood is as dry as practicable. The cylinder shall be relieved continuously or frequently enough to prevent condensate from accumulating in sufficient quantity to reach the wood. Before the preservative is introduced the cylinder shall be drained of condensate.

(c) Ties seasoned by boiling in preservative shall not be heated above the minimum temperature sufficient to evaporate the moisture under the existing pressure. Boiling shall

continue until the rate of condensation of water does not exceed 1/10 of a pound per cubic foot of wood per hour.

4. *Preparation for Treatment.* Any charge of ties shall be confined to one kind or designated group or kinds of wood, of pieces approximately equal in size and moisture and sapwood content, into which approximately equal quantities of preservative can be injected, on which all necessary framing, boring, or chamfering shall have been done, and so separated as to insure contact of preservative, and steam if used, with all surfaces.

5. *Manner of Treatment.* The ranges of pressure, temperature, and time duration shall be controlled so as to result in maximum penetration by the quantity of preservative injected, which shall permeate all of the sapwood, and as much of the heartwood as practicable. The vacuum requirements stipulated are those at sea-level, and necessary corrections shall be made for altitude.

6. *Retention of Preservatives.* No charge shall contain less than 95% nor more than 110%, of the quantity of preservative that may be specified. The amount of preservative retained shall be calculated on the basis of preservative at 100° F., from readings of working-tank gauges, or scales, or from weights before and after treatment of at least 1/5 of the number of loaded trams on suitable track scales, checked as may be desired by the purchaser's representative.

7. *Determination of Penetration.* Penetration shall be determined by sampling ties in each charge, as may be desired by the purchaser's representative. Any holes which may be bored shall be filled with tight-fitting treated plugs.

8. *Plant Equipment.* Treating plants shall be equipped with the thermometers and gauges necessary to indicate and record accurately the conditions at all stages of treatment, and all equipment shall be maintained in condition satisfactory to the purchaser. The apparatus and chemicals necessary for making the analyses and tests required by the purchaser shall also be provided by plant operators, and kept in condition for use at all times.

Preservatives.

9. The preservative or preservatives used shall be the most suitable and available of the following standards of the American Wood-Preservers' Association:

Creosote Oil (Grade 1) for Ties and Structural Timber.
Creosote Oil (Grade 2) for Ties and Structural Timber.
Creosote-Coal-Tar Solution for Ties and Structural Timber.
Creosote Oil (Grade 3) for Ties and Structural Timber.
Zinc Chloride.
Water-Gas-Tar Solution for Admixture with Zinc Chloride.
Water-Gas-Tar Distillate for Admixture with Zinc Chloride.

Amount of Preservatives To Be Used.

10. Creosote:
    - Full-cell process, at least 10 lbs. per cubic foot of cross-ties.
    - Empty-cell process, without initial air, at least 6 lbs. per cubic foot of ties.
    - Empty-cell process, with initial air, at least 5 lbs. per cubic foot of ties.

    Zinc Chloride:
    - One-half pound dry salt per cubic foot of ties.

    Creosote-Zinc Chloride:
    - Three pounds of oil and one-half pound of dry salt per cubic foot of ties.

Treating Operations.

11. (a) Oil Treatment:
    - Full-Cell Process.
    - Empty-Cell Process, without initial air.
    - Empty-Cell Process, with initial air.

    (b) Salt Treatment.

    (c) Oil-Salt Treatment.

Oil Treatment.

12. *Full-Cell Process.* (a) Ties shall be subjected to a vacuum of sufficient intensity and duration to insure that the wood is as dry and free from air as practicable, and to permit a retention of the specified number of pounds of preservative per cubic foot of wood. In no case shall the vacuum be maintained at less than 24 ins. for less than 30 minutes.

(b) The preservative shall be introduced and the cylinder filled without breaking the vacuum. The pressure shall then be raised gradually to and maintained at a minimum of 100 lbs. per square inch until the required quantity of preservative is injected into the wood, or until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. The temperature of the preservative during the pressure period shall be not less than 150° F., nor more than 200° F., and shall average at least 180° F. After pressure is completed the cylinder shall be emptied speedily of preservative, and a vacuum of not less than 22 ins. promptly created and maintained until the ties can be removed from the cylinder free of dripping preservative.

13. *Empty-Cell Process, With Initial Air.* (a) Ties shall be subjected to air pressure of sufficient intensity and duration to provide under a vacuum the ejection of surplus preservative, and to insure a retention and proper distribution of the specified number of pounds of preservative per cubic foot of wood.

(b) The preservative shall be introduced between 150° F. and 200° F., the cylinder pressure being maintained constant until the cylinder is filled with preservative. The pressure shall then be raised gradually to and maintained at a minimum of 150 lbs. per square inch until there is obtained the largest practicable volumetric injection that can be reduced to the required retention by a quick high vacuum, or until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. The temperature of the preservative during the pressure period shall be not less than 150° F., nor more than 200° F., and shall average at least 180° F. After pressure is completed the cylinder shall be emptied speedily of preservative, and a vacuum of not less than 24 ins. promptly created and maintained for not less than 30 minutes until the quantity of preservative injected is reduced to the required retention and the wood can be removed from the cylinder free of dripping preservative.

14. *Empty-Cell Process, Without Initial Air.* (a) The preservative between 150° F. and 200° F. shall be introduced to the ties until the cylinder is filled. Pressure shall then be raised gradually to and maintained at a minimum of 100 lbs. per square inch until there is obtained the largest practicable volumetric injection that can be reduced to the required retention by a quick high vacuum, or until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. The temperature of the preservative during the pressure period shall be not less than 150° F., nor more than 200° F., and shall average at least 180° F. After pressure is completed the cylinder shall be emptied speedily of preservative and a vacuum of not less than 24 ins. promptly created and maintained for not less than 30 minutes until the quantity of preservative injected is reduced to the required retention and the wood can be removed from the cylinder free of dripping preservative.

Salt Treatment.

15. (a) The treating solution, which shall not have a strength exceeding 5%, determined by the American Wood-Preservers' Association "Standard Method of Analysis for Zinc Chloride," and which shall be no stronger than necessary to obtain the required retention of preservative with the largest volumetric absorption practicable, shall be thoroughly mixed before use.

(b) Air-seasoned cross-ties shall be steamed in the cylinder for not less than one hour or more than two hours, at a pressure of not more than 20 lbs. per square inch. After steaming is completed a vacuum of at least 24 ins. shall be maintained for not less

than 30 minutes until the wood is as dry and free of air as practicable. If the vacuum is broken while the condensate is being drained from the cylinder a second vacuum as high as the first shall be created. The preservative shall be introduced without breaking the vacuum until the cylinder is filled. The pressure shall then be raised gradually to and maintained at a minimum of 100 lbs. per square inch until the required quantity of preservative is injected into the cross-ties, until less than 5% of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased while the pressure has been held continuously at 150 or more pounds per square inch. The temperature of the preservative during the pressure period shall be not less than 140° F., nor more than 170° F., and shall average at least 150° F. After the pressure is completed the cylinder shall be emptied speedily of preservative and a vacuum of not less than 24 ins. promptly created and maintained for not less than 30 minutes or until the wood can be removed from the cylinder free of dripping preservative.

Oil-Salt Treatment.

16. (a) The preservative mixture shall be composed of the volumetric proportion of creosote oil and zinc chloride solution of the necessary strength required to obtain the specified retention with the largest volumetric injection that is practicable, and shall be agitated in the working tank and cylinder so as to insure thorough mixing before and while the cylinder is being filled with preservative, and while the preservative is being injected into the ties. The strength of the zinc chloride solution shall not exceed 5% and shall be determined by the American Wood-Preservers' Association "Standard Method of Analysis for Zinc Chloride."

(b) Air-seasoned ties shall be steamed in the cylinder for not less than one hour, nor more than two hours, at a pressure of not more than 20 lbs. per square inch. After steaming is completed a vacuum of at least 24 ins. shall be maintained for not less than 30 minutes until the wood is as dry and free of air as practicable. If the vacuum is broken while the condensate is being drained from the cylinder, a second vacuum as high as the first shall be created. The mixture of preservatives shall then be introduced without breaking the vacuum until the cylinder is filled. The pressure shall then be raised gradually to and maintained at a minimum of 100 lbs. per square inch until the required quantity of preservative is injected into the ties, or until less than 5% of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased while the pressure has been held continuously at 150 or more pounds per square inch. The temperature of the preservative during the pressure period shall be not less than 150° F., nor more than 200° F., and shall average at least 180° F. After the cylinder is emptied of preservative, a vacuum of not less than 24 ins. shall be maintained until the timber can be removed from the cylinder free of dripping preservative.

[H. A. L.]

Sugar Prices.

96° Centrifugals for the Period March 17, 1924 to June 11, 1924.

Date	Per Pound	Per Ton	Remarks
Mar. 17, 1924	6.845¢	$136.90	Cubas, 6.91; Porto Ricos, 6.78.
" 19	6.65	133.00	Cubas.
" 20	6.75	135.00	Porto Ricos, 6.78, 6.72.
" 25	6.65	133.00	Porto Ricos.
" 28	6.78	135.60	Cubas.
April 1	6.65	133.00	Cubas.
" 3	6.50	130.00	Cubas, 6.53, 6.47.
" 4	6.53	130.60	Porto Ricos.
" 5	6.65	133.00	Porto Ricos.
" 8	6.53	130.60	Cubas.
" 9	6.40	128.00	Cubas.
" 10	6.435	128.70	Cubas, 6.40, 6.47.
" 11	6.28	125.60	Cubas.
" 14	6.09	121.80	Cubas, 6.15, 6.03.
" 15	5.90	118.00	Cubas.
" 16	6.28	125.60	Porto Ricos.
" 21	6.15	123.00	Porto Ricos.
" 22	6.2167	124.33	Porto Ricos, 6.15; Philippines, 6.22; Cubas, 6.28.
" 23	6.40	128.00	Porto Ricos.
" 25	6.28	125.60	Porto Ricos.
" 30	6.215	124.30	Porto Ricos, 6.28; Cubas, 6.15.
May 1	6.03	120.60	Cubas.
" 5	5.90	118.00	Cubas.
" 7	5.78	115.60	Cubas.
" 12	5.84	116.80	Cubas, 5.90, 5.78.
" 13	5.5467	110.93	Cubas, 5.65, 5.53, 5.46.
" 14	5.53	110.60	Cubas.
" 15	5.715	114.30	Cubas, 5.78, 5.65.
" 16	5.745	114.90	Cubas, 5.78, 5.65, 5.71; Philippines, 5.84.
" 19	5.65	113.00	Cubas.
" 20	5.53	110.60	Porto Ricos.
" 22	5.40	108.00	Porto Ricos.
" 24	5.15	103.00	Porto Ricos.
" 26	5.055	101.10	Cubas, 5.09, 5.02.
" 27	5.005	100.10	Porto Ricos, 5.02; Philippines, 4.99.
June 2	5.21	104.20	Porto Ricos.
" 3	5.12	102.40	Cubas, 5.15, 5.12; Porto Ricos, 5.09.
" 4	5.055	101.10	Cubas, 5.09, 5.02.
" 9	5.15	103.00	Cubas.
" 10	5.085	101.70	Cubas, 5.15, 5.02.
" 11	5.02	100.40	Cubas.